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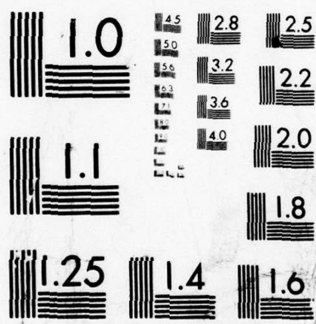

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DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHNICAL NOTE NO. 5-78

PRELIMINARY SPECIFICATION AND SIZING REQUIREMENTS FOR SECTOR AND NODAL SYSTEM CONTROL PROCESSING ELEMENTS

NOVEMBER 1978

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TECHNICAL NOTE NO. 5-78

PRELIMINARY SPECIFICATION AND SIZING

REQUIREMENTS FOR SECTOR AND NODAL

SYSTEM CONTROL PROCESSING ELEMENTS

NOVEMBER 1978

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FOREWORD

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EXECUTIVE SUMMARY

This Technical Note is an examination of the sizing requirements for future DCS System Control Computer Systems at the sector and nodal levels. A detailed definition of required functions is presented followed by both a processor memory and processor communication sizing examination. This TN has been prepared to provide full documentation of the background and considerations that were used in the ATEC sizing efforts that were prepared for the USAF Electronic Systems Division.

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A heuristic procedure for sizing system control processing elements is described and associated sizing estimates are made. These figures are based on a model of a single processor with one level of segmented contiguous addressable storage, which gives a reasonable first estimate. The processor, main storage, secondary storage, display and communications requirements are described. The techniques and rationale follow basically heuristic procedures complemented by some analytic techniques.

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I. INTRODUCTION

The DCS consists of a heterogeneous mixture of common user and dedicated networks, transmission facilities and control elements which provide the Department of Defense with a worldwide communications capability. The major switched networks include AUTOVON, AUTODIN and AUTOSEVOCOM; the transmission facilities are divided up among radio, cable and satellite equipments. The control elements comprise the System Control subsystem.

The purpose of this report is to examine the sizing requirements of the future DCS System Control Computer Systems at the sector and nodal levels. This is accomplished by first examining the system control functions and by then decomposing the system control processor into five functional/physical components. Each component will then be sized according to a model described in Section III, for both the sector and nodal level elements.

This report is based upon efforts which were completed in 1977 in support of the USAF Electronic Systems Division (ESD). The results reported here were provided to ESD for inclusion in the System Specification for the Automated Technical Control (ATEC) production equipment. The minimum sizing requirements for the ATEC processors, to support the system control and technical control functions, is a critical dimension to insuring the long term utility of ATEC to provide the badly needed automation of the lower three levels of the system control hierarchy. The results shown here were embodied in the specification, and were met or exceeded by the system proposed by the selected contractor. This report has been prepared to document this work, to show how the estimation techniques and analysis were applied to the ATEC system, and to provide full documentation of the background and considerations included in the sizing estimates.

II. BACKGROUND

System Control for the DCS employs a five-level control hierarchy, which includes functional capabilities from the worldwide control level down to the station control level. The DCS System Control subsystem provides as the means whereby DCS assets are used to maintain and restore maximum DCS performance under changing traffic conditions, natural or man-made stresses, disturbances and equipment failures. These goals are achieved through timely acquisition of system performance data, facility and traffic load status and service quality indications, and subsequent timely control of DCS assets.

Level I of the five level hierarchy administers worldwide control and is centered at the Defense Communications Agency Operations Center (DCAOC) in Arlington, Va. Level II administers theater control and is centered at the Area Communication Operation Centers (ACOC). The third level administers sector control and is situated at the Facility Control Office (FCO) while level IV, nodal control, is centered at the Major Technical Control Centers. The station control, Level V, is located at the equipment or patch and test facility level.

This report is primarily concerned with the sizing requirements of the sector and nodal levels, the third and fourth levels in the five-level hierarchy. To accomplish this task, a definition of system control functions at the sector and nodal levels are as defined in the "DCS Concept for System Control" /11/ and the "Technical Overview of the System Control Improvement Program" /12/. Using the unified approach, the task of augmenting and utilizing the proposed Automated Technical Control (ATEC) equipment as a common equipment basis for a initial unified system control capability was examined. This report documents that effort and presents performance and sizing requirements for augmenting existing and proposed ATEC equipment.

III. METHODOLOGY

The techniques employed in this effort are heuristic, and permit the utilization of the problem solver's analytical insight into the problem area /1, 2, 3, 4, 5/. While a mathematically rigorous approach could have been utilized, it would not necessarily yield more accurate results, due to uncertainties inherent in the estimation of future requirements and functions.

The model used in this analysis was of a single processor system with one level of contiguous addressable main storage and one level of secondary storage for programs and data. Contained in the model is a complete list of functions that are to be performed. Once these functions were determined, a sizing estimate was made for each of these functions based on other studies and past experience, and a partitioning scheme for main memory was chosen. The major emphasis of the partitioning scheme was that it be implementable, easy to visualize, and allow for a minimum number of program transfers. This model is used in this analysis because of its inherent computational simplicity and its similarity to more dynamic but complex implementations. A primary objective of any memory partitioning sizing model is to assure good performance characteristics by minimizing the possibility of thrashing (an excessive amount of processor overhead associated with memory overlaying) but also using reasonable operational units for main storage size.

The model used in this report considers the operational environment of the System Control functions. Some functions will be executed very rapidly and continuously and if possible are best left resident in main storage, while other functions are executed so infrequently that they can be left in secondary storage and transferred in when necessary. Still other functions are used often but are so large that it is best to require only an "operational amount" of space in the partitioning model. In this case a form of either chaining or overlay structure can be implemented so that storage can be used efficiently.

A major problem associated with a sizing analysis of this type is determining the required speed for the processor. For this sizing estimate it was considered prudent, considering the existing experiments and contracts for equipment such as ATEC and TCCF, to require a memory cycle time of 750 nanoseconds. This memory speed is readily available at reasonable cost. It is understood that memory cycle time is one of several parameters with respect to throughput and power of a machine. Major and minor cycle times are also needed along with the number of cycles required to execute a single instruction. In addition the "power" of instructions would also have to be estimated. Another throughput measure giving results in the form of MIPS (millions of instructions per second) could be estimated by various means. A standard means of achieving this measure is the

use of standard instruction mixes. This method is acceptable for determining an average throughput of a single processor system.

In Section IX the communications throughput requirements are determined for a fixed M/D/1 queueing model. The M/D/1 model was used because system control messages are usually formatted to be of fixed size, and the M/D/1 model is designed for a single server queueing size with a Poisson arrival but a deterministic service time.

Secondary memory sizing requirements are estimated by deciding what must reside in secondary storage, the size of these elements and their expected expansion factors. This approach was taken with some attention given to the possible fragmentation of data and instructions between main and secondary storage. Secondary storage media were studied and compared to the program requirements and additional space was allocated for growth and fragmentation.

The requirements of the display unit were based upon examination of the operator skills, information to be displayed, desired response times, availability, the need for backup information and historical data. With these requirements in mind, the number and speed of the display elements and additional equipment required were determined.

IV. FUNCTIONS CONSIDERED

The nature of System Control for the DCS is illustrated in Figure 1 which shows the major functions that must be performed, the events that cause interaction among the System Control and the DCS and the various subsystems, existing, or under development, from which System Control draws its information. In particular the analysis is concerned with how System Control functions can easily be integrated into the ATEC equipment.

The overall function of DCS System Control is defined here to be all those on-line and off-line activities which are performed to provide the best possible service to DCS users within the limitations and status of the existing operable DCS facilities. Real-time or near-real-time (implying seconds, minutes, and possibly hours,) activities are those performed "on-line" as opposed to "off-line" management planning and engineering activities.

Within the overall system control functions, Network Control maintains overall visibility and control of the network as an entity, providing end-to-end communications services to the users. Traffic Control maintains efficient communication flows through the nodes and transmission facilities. Transmission Control maintains control and detailed visibility of the operation, maintenance, configuration and status of the transmission facilities. Switch Control is concerned with maintaining control and visibility of operation, maintenance and status of circuit, message and packet switches in the DCS networks.

A hierarchical decomposition of functions starts with the highest level system (overall) function (e.g., overall DCS System Control) and, in successive steps, reduces this to a number of major functions. At each level, every identified function is broken down into smaller functional areas. The decomposition is complete when an obvious implementation of the lowest level functions exists, and their inputs/outputs can be completely identified. This level of decomposition is sufficient for the analysis of system performance requirements, although the functions would undergo further decomposition when an exact implementation is designed. The major functions - Network/Traffic Control, Transmission Control, and Switch Control comprise a suitable (but certainly not unique) first level decomposition.

Further decomposition of each major function follows a similar breakdown. Lower level functions performed include data collection, performance assessment, fault detection/isolation, control implementation, and reporting. Network/Traffic Control is unique in that it is more effectively decomposed into fault isolation, network trouble analysis, traffic and status data collection, network traffic analysis and control, network service evaluation, resource

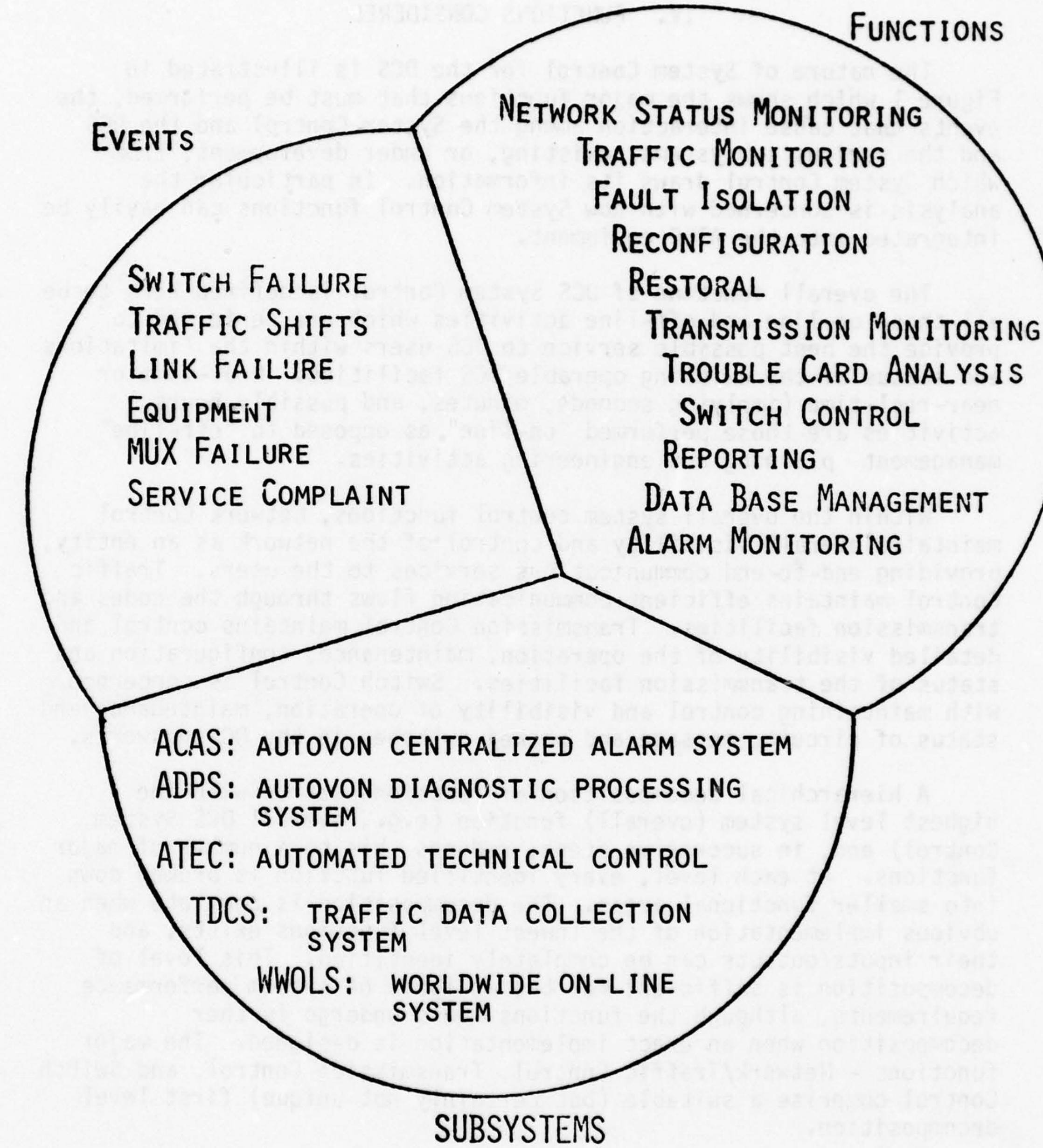


FIGURE 1 - THE NATURE OF SYSTEM CONTROL IN THE DCS

allocation, reconfiguration and trending, and routine maintenance, test, and alignment scheduling.

1. DCS SYSTEM CONTROL MAJOR FUNCTIONS

Each of the communications control functions is further described in this section. For each function there are descriptions of what processing is performed, its inputs and outputs, and how that function can be implemented. An additional level of decomposition yields the functional breakdown tablulated below. The planning elements of DCS System Control are excluded; only real-time control functions are included.

a. Network/Traffic Control.

- Network Trouble Analysis
- Network Fault Isolation
- Circuit/Message/Packet Switched Network Traffic and Status Data Collection
- Circuit/Message/Packet Switched Network Traffic Analysis and Control
- Network Service Evaluation, Resource Allocation, Reconfiguration and Trending
- Routine Maintenance Test, Alignment Scheduling
- Reporting.

b. Switch Control.

- Data Collection
- Performance Assessment
- Trouble Analysis and Fault Isolation
- Control Implementation
- Reporting.

c. Transmission Control.

- Data Collection
- Performance Assessment

- Trouble Analysis and Fault Isolation
- Control Implementation
- Reporting.

Table I shows the information flow between the three major DCS System Control functions. In addition there are a number of other System Control functions which perform utility tasks. These are tabulated below.

d. Utility Functions.

- File and Data Base Management
- Message Error Checking
- Data Conversion
- Display Generation
- Operator Interface
- Orderwire Protocol
- Executive Control/Task Scheduling
- Maintenance and Diagnostics
- System Initialization and Bootstrap
- Disc I/O Handler
- Processor Monitor
- System Fault Recognition
- Interrupt Administration
- General Purpose Subroutines.

In the remainder of this section, these functions are described in more detail and their inputs and outputs are defined.

2. NETWORK/TRAFFIC CONTROL

The main purpose of network/traffic control is to coordinate and interface all lower level DCS System Control, DCS users, and Real Time Adaptive Control (RTAC) activities. Summaries of common user network traffic data, equipment status and trouble reports,

TABLE 1
INFORMATION FLOWS
BETWEEN MAJOR FUNCTIONAL AREAS OF SYSTEM CONTROL

From \ TO	NETWORK/TRAFFIC CONTROL	TRANSMISSION CONTROL	SWITCH CONTROL
NETWORK/ TRAFFIC CONTROL	o	• RECONFIGURATION DIRECTIVES • INITIAL DIAGNOSTIC REFERRALS OF TRANSMISSION FAULTS • SPECIAL TEST REQUESTS	• REQUESTS FOR SPECIAL CALL & TRAFFIC DATA • SWITCH CONTROL DIRECTIVES • INITIAL REFERRALS OF SWITCH FAULTS
TRANS. CONTROL	• OUTAGE REPORTING • DIAGNOSTIC REFFERAL REPORTING • ESTIMATES OF TIMES TO RESTORE/RECON-FIGURE	o	• REQUESTS FOR TROUBLE CARD DATA • TEST & REFERRAL COORDINATION
SWITCH CONTROL	• CALL, TRAFFIC & SWITCH CONGESTION DATA • EQUIPMENT ALARMS • CONTROL ACTIONS • PRESCREENED TROUBLE CARD DATA & REPORTS	• EXCEPTION REPORTS ON TRANSMISSION • REQUESTED TROUBLE CARD DATA • TEST & RESTORAL COORDINATION	o

transmission equipment status and trouble reports, and RTAC trouble reports are gathered at the network/traffic control level for network system analysis and control. The major functions performed at this level include network trouble analysis, network fault detection/isolation, network service evaluation, resource allocation and reconfiguration, switch traffic and status data collection, switch traffic analysis and control, and routine maintenance test and alignment scheduling and reporting. The interrelationships of these functions are shown in Figure 2. The functions are individually discussed below.

a. Network Trouble Analysis. Trouble reports and system outage reports from lower DCS control levels (including RTAC) and DCS users are analyzed by this function. When reported system outages are expected to affect user service for a significant period of time (especially critical users), network performance status and trouble summary reports will be generated and sent to the network service evaluation, resource allocation and reconfiguration function. Reports from different sources are correlated. This requires a complete DCS and partial DSCS (only DCS interconnected) network connectivity, equipment configuration and status, and equipment translation data base. When analysis results point to a subsystem in which a fault is suspected, network fault isolation requests may be generated.

Network troubles that are not resolved by the network fault isolation procedures are recorded and analyzed by this function on a longer term basis. These troubles could be transient problems or gradual system degradations. In addition, common user network traffic summaries from the network resource allocation and reconfiguration function are also analyzed (e.g., trunk usage and holding time analysis). When analysis results indicate replacement and alignment of equipment or further fault isolation is needed, requests will be generated and sent to the appropriate functions (network fault isolation, RTAC or affected DCS stations). This function is envisioned to be implemented principally as a man-machine, query-response activity drawing from many of the inputs and outputs of the network fault isolation and network resource allocation and reconfiguration functions.

- Inputs to Network Trouble Analysis
  - DCS terrestrial transmission status and trouble reports
  - DSCS status and trouble reports
  - Switch network status and trouble reports
  - DCS user and operator trouble reports

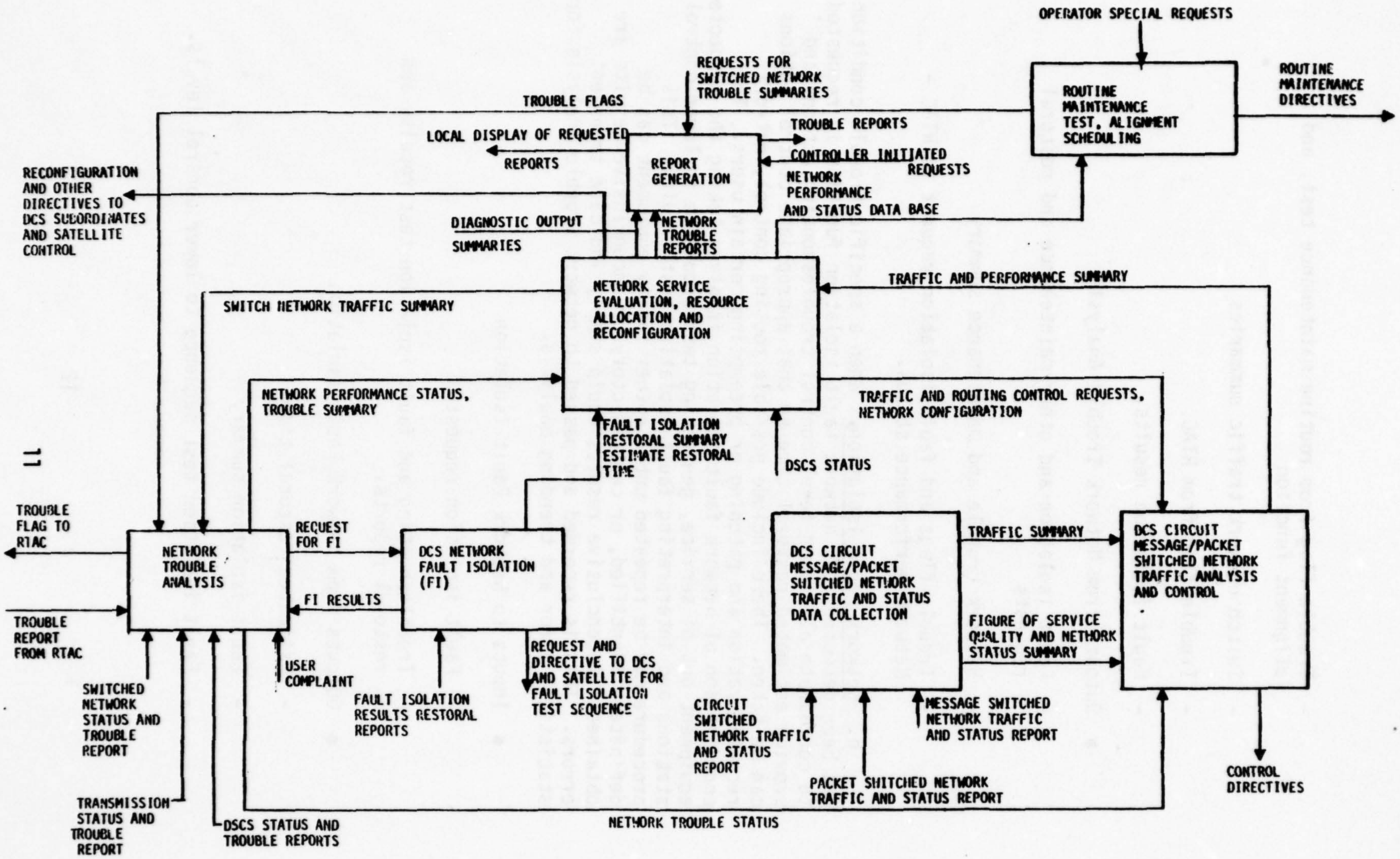


FIGURE 2 - NETWORK SYSTEM CONTROL FUNCTIONAL FLOW DIAGRAM

- Trouble flag from routine maintenance test, and alignment function

- Switch network traffic summaries

- Trouble flag from RTAC

- Fault isolation results.

● Outputs from Network Trouble Analysis

- Fault isolation and other maintenance and restoral requests

- Network trouble and maintenance summary

- Trouble flags and fault isolation request to RTAC - Network performance status.

b. <u>Network Fault Isolation</u>. When a specific trouble condition has been detected, the network fault isolation function is requested to coordinate all lower level control troubleshooting actions and provide estimated restoral time so that appropriate control actions can be taken. These include possible routing control, network reconfiguration and patching or preempting certain users. The coordination of network fault isolation involves taking the suspected equipment out of service, generating test sequences to lower control stations and interpreting fault isolation test results. This procedure may be repeated until either faulty equipment can be definitely identified, or contradictory or inconclusive results are obtained. Inconclusive results could simply indicate transient errors. This is recorded and passed to network trouble analysis for statistical error and trending analysis.

● Inputs to Network Fault Isolation

- Fault isolation requests

- Troubleshooting and fault isolation test results and restoral reports.

● Outputs from Network Fault Isolation

- Estimated restoral time

- Fault isolation summary

- Fault isolation test sequence to lower control levels.

c. Circuit/Message/Packet Switched Network Traffic and Status Data Collection. This function monitors the switch status and traffic loading conditions of all DCS common user networks. Summaries of switch traffic, alarm parameters and call parameters are processed at this level to provide complete real-time visibility of the DCS common user networks, and figures of service quality for various types of users and portions of the networks. These processed network visibility and service quality summaries are then used by the network traffic analysis and control function.

- Inputs to Circuit/Message/Packet Switched Network Traffic and Status Collection
  - Circuit switched network traffic and status reports
  - Message switched network traffic and status reports
  - Packet switched network traffic and status reports.
- Outputs from Circuit/Message/Packet Switched Network Traffic and Status Data Collection
  - Point-to-point traffic summary for user type
  - Figure of service quality and network status summaries

d. Circuit/Message/Packet Switched Network Traffic Analysis and Control. The processed traffic flow summary and network status is analyzed based on the acceptance level for each user type and the total traffic demand in the common user networks. If the figure of service quality is felt unacceptable for a certain user type, control actions may be selected here. These include routing table updates, inhibition of certain lower priority traffic from portions of the network and switching of common equipment controls. The controls are implemented by sending directives to various switch sites involved.

- Inputs to Circuit/Message/Packet Switched Network Traffic Analysis and Control
  - Point-to-point traffic summary by user type
  - Figure of service quality and network status summaries
  - Traffic and routing control request and network reconfiguration function
  - Network trouble status.
- Outputs from Circuit/Message/Packet Switched Network Traffic Analysis and Control

- Control directives

- Traffic and performance summary

e. Network Service Evaluation, Resource Allocation and Reconfiguration. Periodic performance summaries of traffic data from DCS common user networks, switch status and outages, and private user near-real-time demands are reported to this function. These reports are analyzed to determine the capacity needed for acceptable network operations, and to determine if network reconfiguration is necessary. Reconfiguration/restoration requests from network fault isolation are also input to this function. If it is decided that channel resources are not distributed properly (to meet various priorities and needs), or that additional channel capacity is needed, directives for network reconfiguration are generated. If satellite channels are involved, interface messages are sent to the appropriate RTAC control elements.

- Inputs to Network Service Evaluation, Resource Allocation and Reconfiguration
  - Network Performance Status (topology and capacity assignment)
  - Traffic and Performance Summary
  - DSCS status
  - Fault Isolation Restoral Summary - estimated restoral time
  - Network Trouble Summary.
- Outputs from Network Service Evaluation, Resource Allocation and Reconfiguration
  - Switched Network Traffic Summary
  - Reconfiguration directives to DCS RTAC elements for implementation
  - Network configuration
  - Network Performance Summary
  - Traffic and Routing Control Requests.

f. Routine Maintenance Test and Alignment Scheduling. The purpose of this function is to test equipment periodically without affecting service (during non-busy period when network capacity exceeds user demand), and try to detect potential troubles that would

otherwise impair service. This function makes use of the available data on network equipment maintained by the network fault isolation and network trouble analysis functions, and performs routine maintenance tests without interfering with normal real-time operations of other control functions. When troubles are detected, flags to the appropriate controls will be raised to trigger needed actions. The scope of this function is limited principally to those long-haul transmission paths which cannot be viewed by a lower level DCS control function.

- Inputs to Routine Maintenance Test and Alignment Scheduling
  - Network performance and status data base
  - Operator special requests.
- Outputs from Routine Maintenance Test and Alignment Scheduling
  - Maintenance test results and flags on possibly failing or degrading equipments
  - Routine Maintenance Directives.

g. Reporting. This function takes selected reports for network level analysis, diagnostic output summaries and requests from the network controller and transmits this information and its responses to the local display.

- Inputs to Reporting
  - Requests for switch network trouble summaries
  - Network trouble reports
  - Diagnostic output summaries
  - Controller initiated requests.
- Outputs from Reporting
  - Local Display of requested reports
  - Trouble Reports.

3. SWITCH CONTROL

Circuit/message/packet switch control provides the control actions for the common user subnetworks that switch traffic via circuit/message/packet switching. While this function could be

decomposed further into functions for each subnet, these subnet functions are described here in a common set for each subnetwork, since the respective functions are nearly identical. The subnetwork functions are data collection, performance assessment, trouble analysis and fault isolation, control implementation, and reporting. Many of these functions are mainly data collection and implementation supports for higher level network/traffic control functions and are performed under supervision from the network/traffic control level. A functional flow diagram of the Switch System Control task is shown in Figure 3.

a. <u>Data Collection</u>. The switch data collection function comprises a traffic peg count, usage and duration parameter scanning, call data scanning, switch alarm scanning and switch trouble card scanning. Some preliminary processing is performed here which includes equipment usage and event duration calculation, and accumulated peg counts.

- Inputs to Data Collection
  - Switch trouble card reports
  - Switch component status and alarms
  - RSJ (Register, Sender, Junctor) states
  - Traffic peg count
  - Traffic usage and component out-of-service duration
  - Traffic control duration.
- Outputs from Data Collection
  - Peg Count over sampling period
  - Call data summary and RSJ States
  - Switch trouble reports
  - Switch alarm states
  - Traffic Usage and Duration data over sampling period.

The functional flow of the Data Collection task is summarized in Figure 4.

b. <u>Performance Assessment</u>. This function interprets the data collection reports and detects any possible trouble conditions. These functions include traffic monitoring, detection, switch alarm

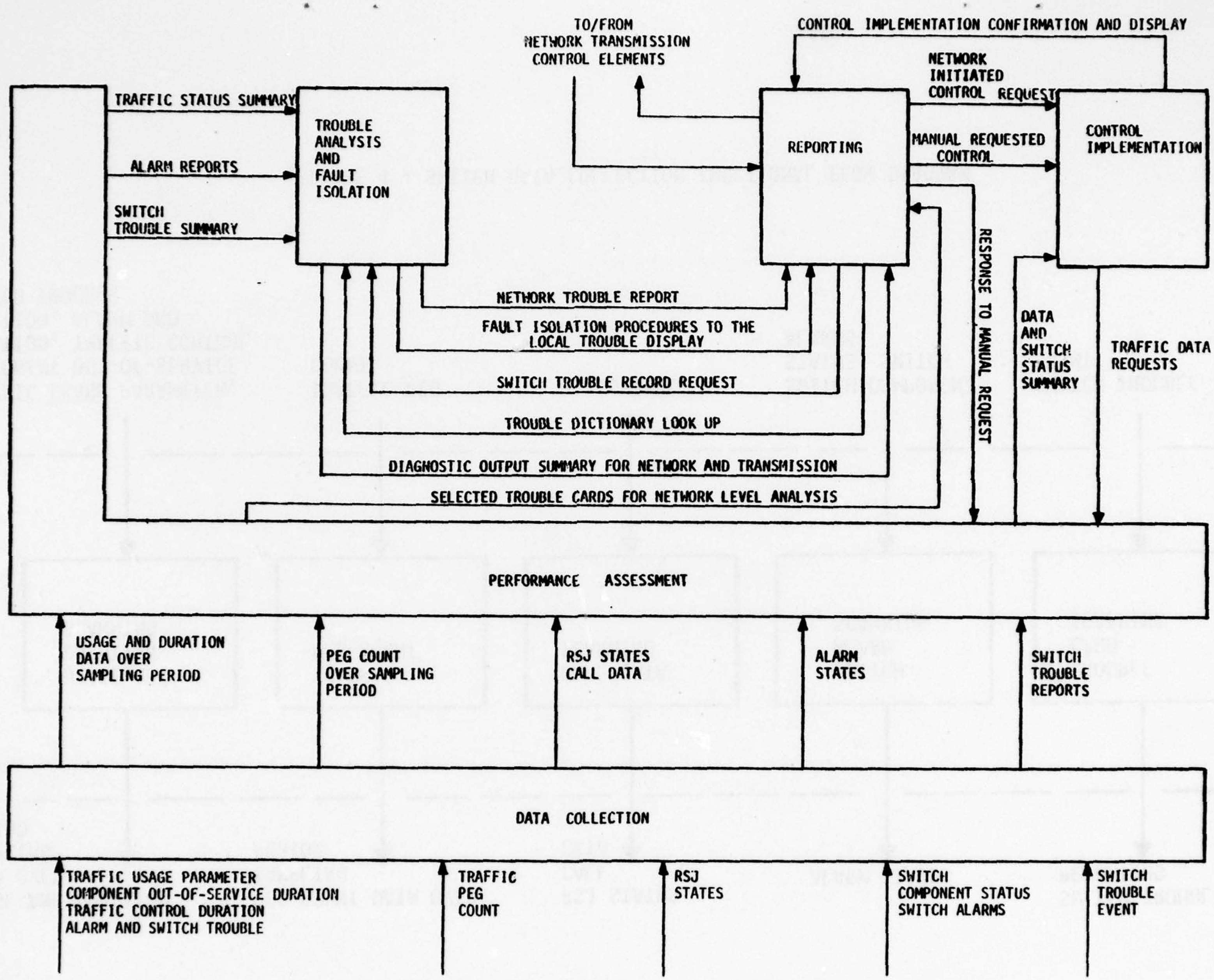


FIGURE 3 - SWITCH SYSTEM CONTROL FUNCTIONAL FLOW DIAGRAM

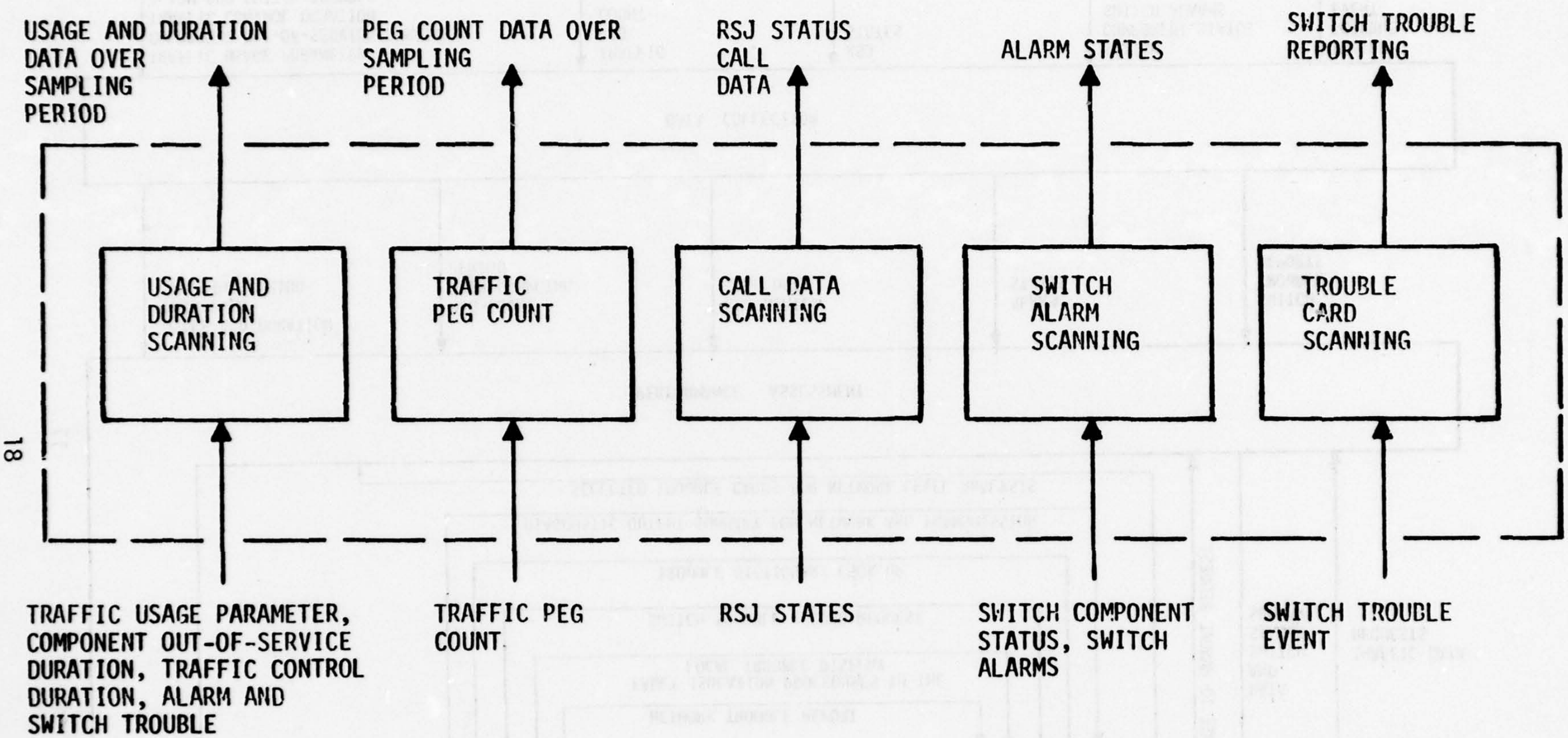


FIGURE 4 - SWITCH DATA COLLECTION FUNCTIONAL FLOW DIAGRAM

interpretation, trouble card sorting, and interpretation and call data monitoring and traffic calculation.

- Inputs to Performance Assessment
  - Peg Count over sampling period
  - Call data summary and RSJ states
  - Switch trouble report
  - Switch alarm states
  - Traffic usage and duration data over sampling period
  - Traffic Data Requests.
- Outputs from Performance Assessment
  - Control Requests and Traffic Status
  - Response to Manual Request
  - Traffic Status Summary
  - Alarm Report
  - Switch Trouble Summary
  - Trouble Card Report for Network Trouble Analysis.

A functional flow diagram of the Performance Assessment task is shown in Figure 5.

c. Trouble Analysis and Fault Isolation. This function suppresses redundant trouble reports, initiates the appropriate fault isolation actions, correlates traffic anomalies with out-of-service reports and forwards network and transmission trouble reports to the appropriate control elements.

- Inputs to Trouble Analysis and Fault Isolation
  - Traffic and Switch status summary
  - Switch trouble condition
  - Switch alarms.

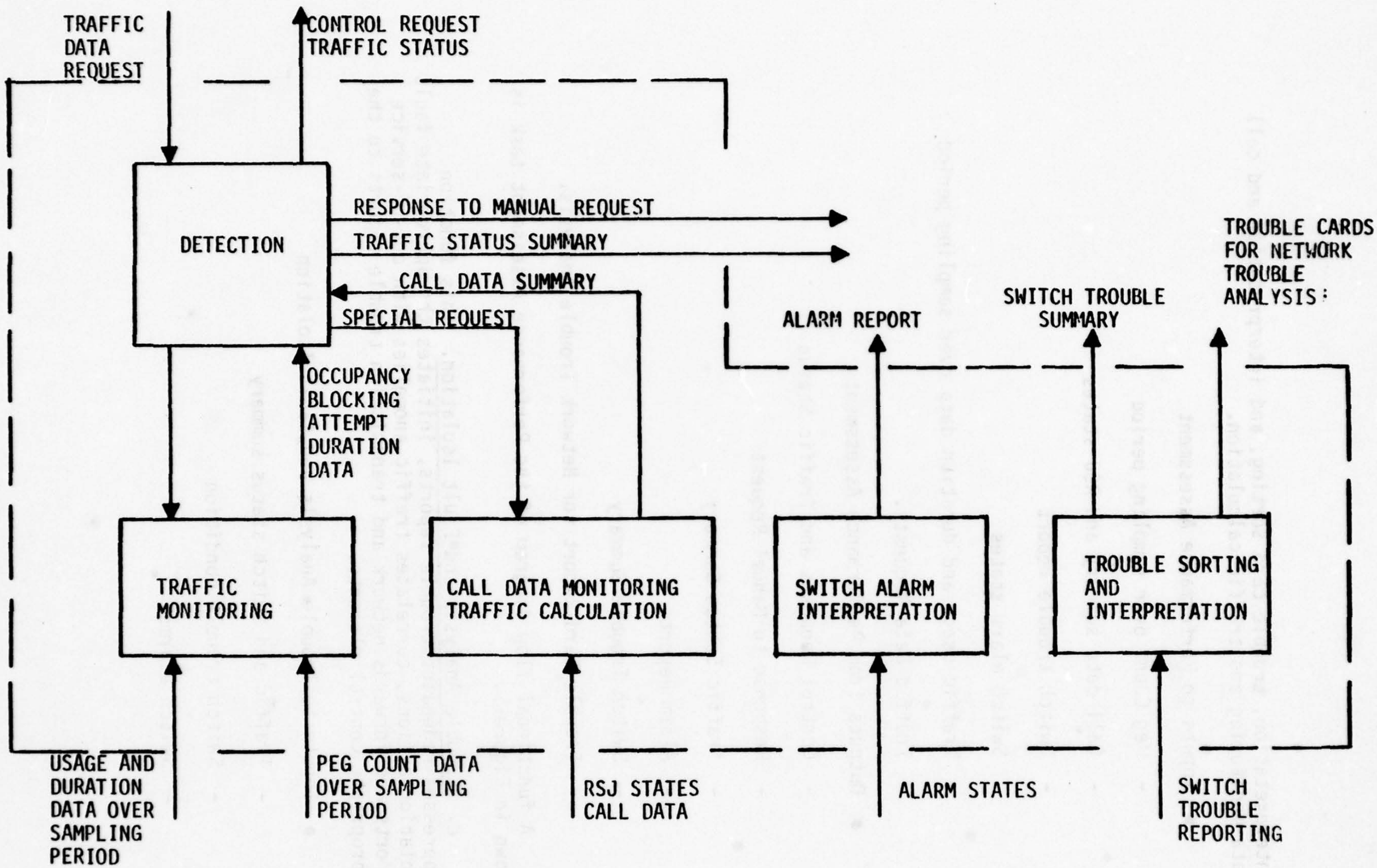


FIGURE 5 - SWITCH PERFORMANCE ASSESSMENT FUNCTIONAL FLOW DIAGRAM

- Outputs from Trouble Analysis and Fault Isolation
  - Trouble reports and status summaries to network/traffic control
  - Fault isolation procedures to the local trouble display.

The functional flow diagram for the Trouble Analysis and Fault Isolation task is shown in Figure 6.

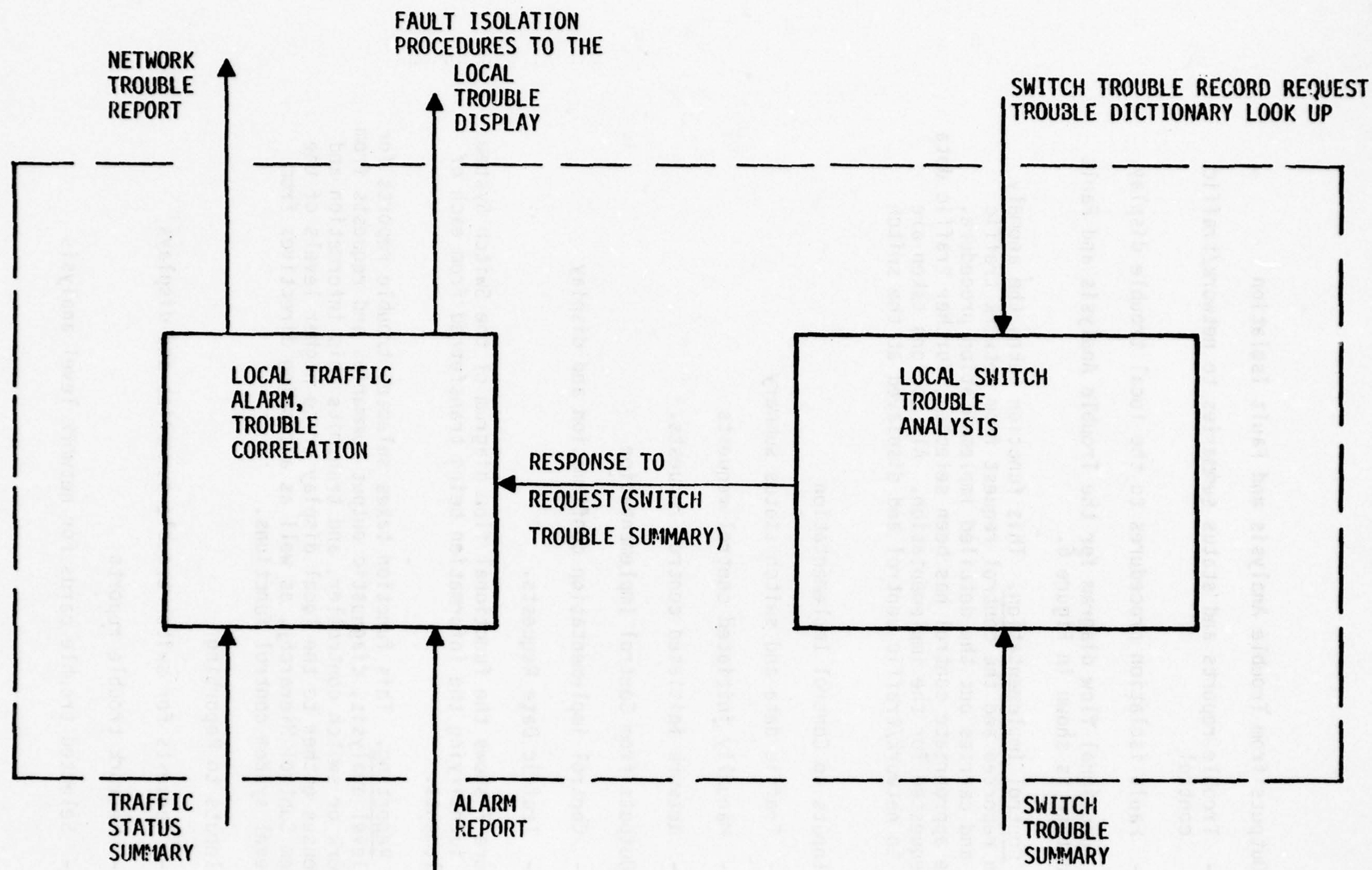
d. Control Implementation. This function takes the anomaly condition reported and the control request from network traffic control, and carries out the detailed implementation procedure. After the appropriate control has been selected, further traffic data may be requested for the implementation. All actions taken are reported to network/traffic control and displayed at the switch level.

- Inputs to Control Implementation
  - Traffic data and switch status summary
  - Manually initiated control requests
  - Network initiated control requests.
- Outputs from Control Implementation
  - Control implementation confirmation and display
  - Traffic Data Requests.

Figure 7 shows the functional flow diagram of the Switch System Control, identifying the information being transferred from each of the subelements.

e. Reporting. This function takes selected trouble reports for network level analysis, diagnostic output summaries and requests from the network or switch controller, and transmits this information and its responses either to the local display or to higher levels of the DCS System Control Hierarchy, as well as accepting directives from higher level system control functions.

- Inputs to Reporting
  - Requests for switch trouble summaries and displays
  - Network trouble reports
  - Selected trouble cards for network level analysis



SWITCH TROUBLE ANALYSIS AND
FIGURE 6 - FAULT ISOLATION FUNCTIONAL FLOW DIAGRAM

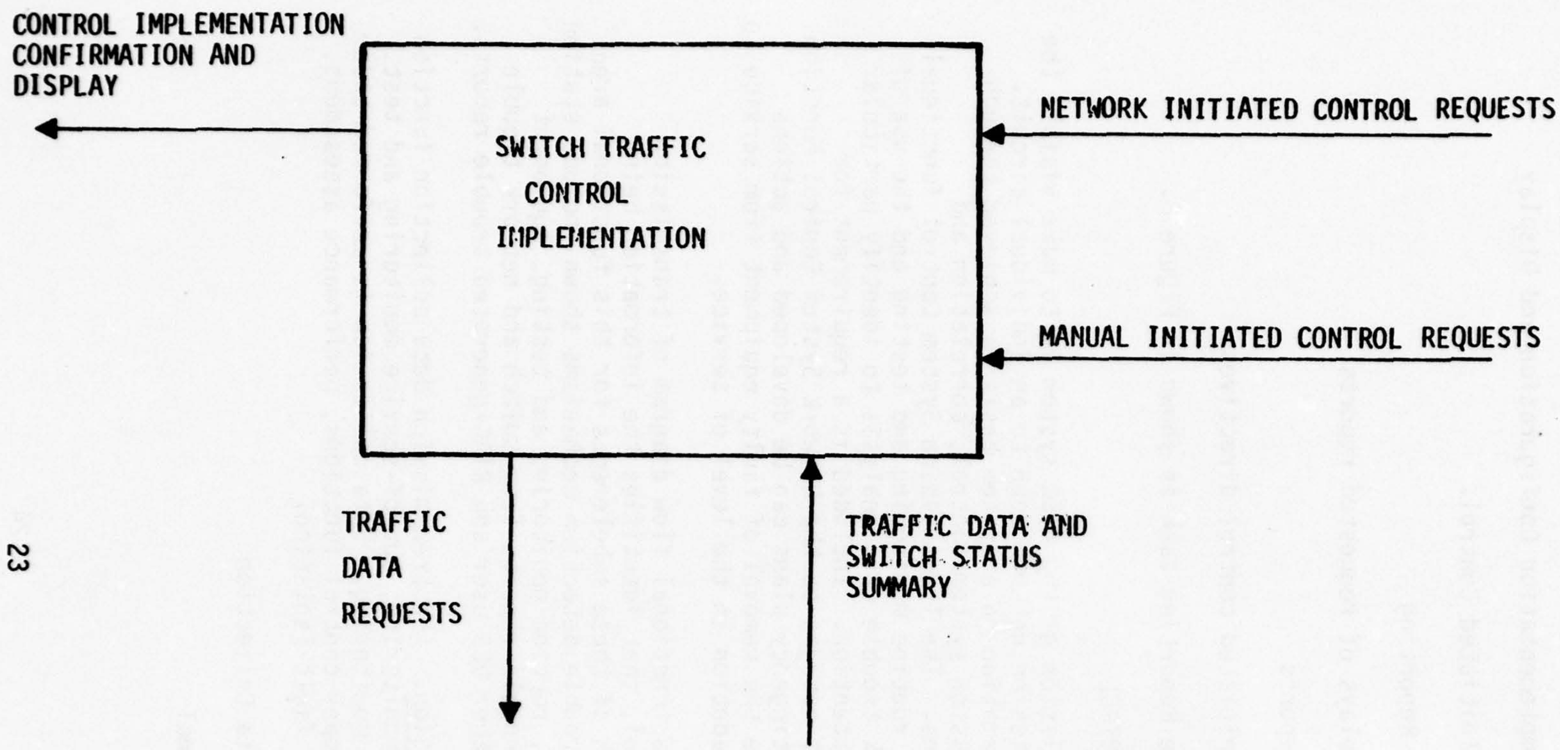


FIGURE 7 - SWITCH CONTROL IMPLEMENTATION FUNCTIONAL FLOW DIAGRAM

- Diagnostic output summaries
- Network initiated control directives
- Control Implementation Configuration and Display
- Manually Initiated Control.

- Outputs from Reporting
  - Local Displays of requested reports
  - Trouble reports
  - Network initiated control directives.

A summary of the Reporting task is shown in Figure 8.

4. TRANSMISSION CONTROL

The principle mission of the ATEC system is to make visible the health of the transmission network down to an individual circuit. The use of this information on a system basis is achieved through higher level transmission system control, correlation and coordination functions. The Transmission System Control functional requirements include routine monitoring and testing and the use of the switch in network trouble card analysis to identify particular circuits requiring attention. Included is a requirement for reporting significant outages to the Network System Control Function so that adequate contingency plans can be developed and actions taken. These include the removal of faulty equipment from service to prevent further degradation in the level of service.

Figure 9 shows a functional flow diagram of transmission monitoring and control, that identifies the information being transferred from each of these subelements for this functional area. Major transmission trouble detection mechanisms shown include station equipment monitoring, routine monitoring and testing, equipment trending analysis, trouble reports from switch and network trouble card analysis, and other DCS user and RTAC-generated trouble reports.

a. Data Collection. The transmission data collection function includes in-service monitoring, out-of-service monitoring and test, and status and alarm monitoring. Data collection is performed under the supervision of upper control functions, performance assessment, trouble analysis and fault isolation.

- Inputs to Data Collection
  - Voice signal

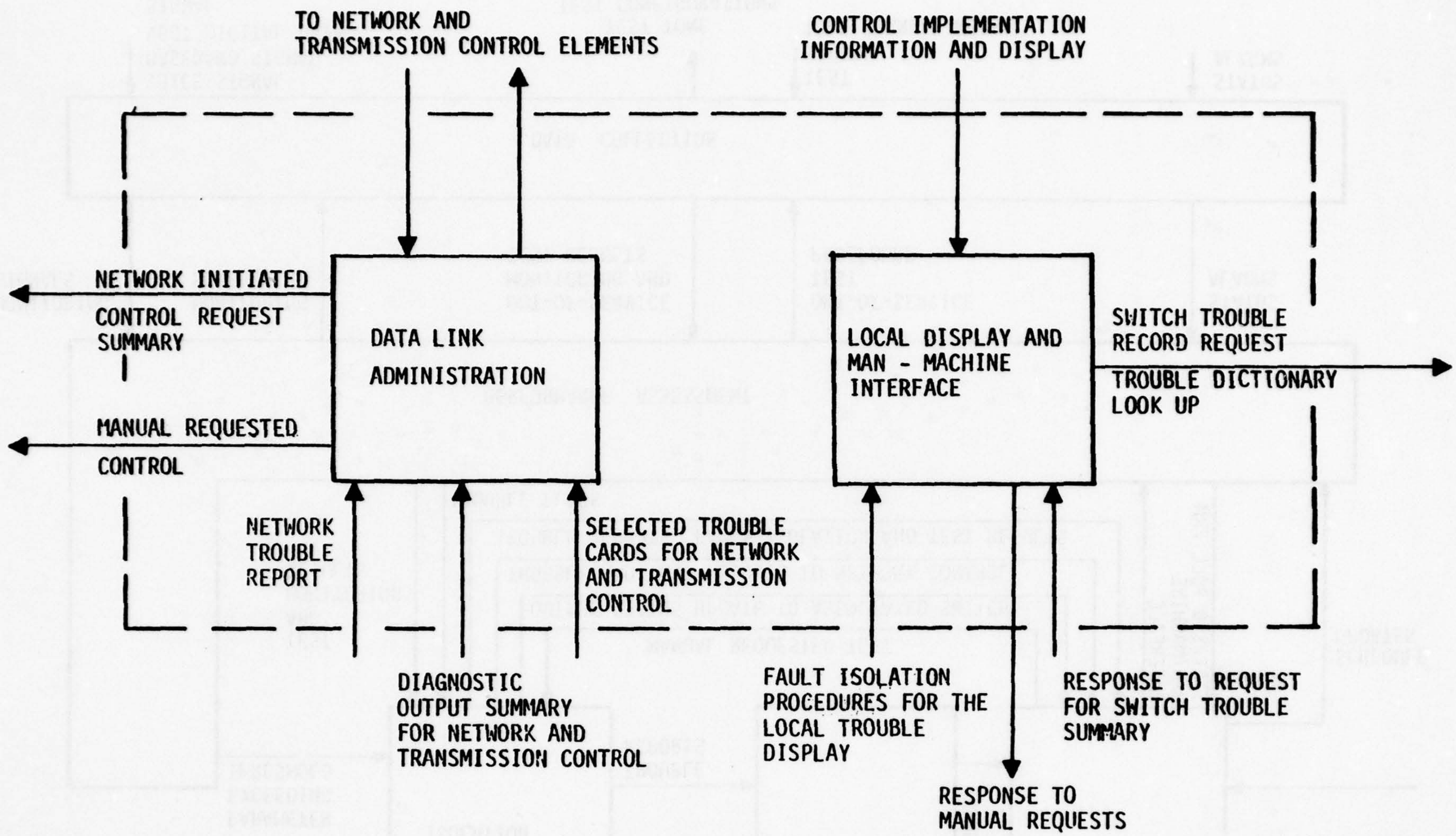


FIGURE 8 - SWITCH REPORTING FUNCTIONAL FLOW DIAGRAM

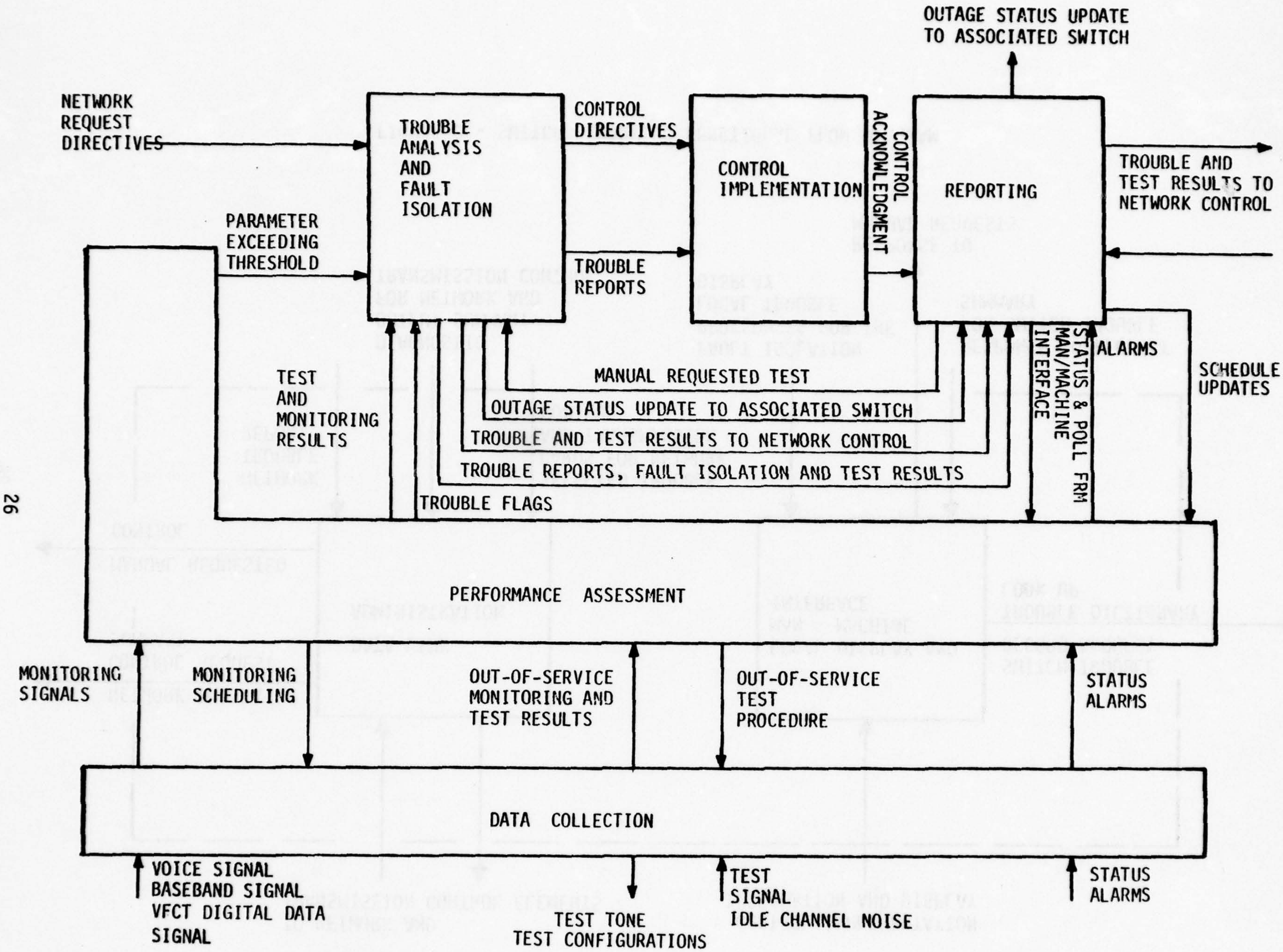


FIGURE 9 - TRANSMISSION SYSTEM CONTROL FUNCTIONAL FLOW DIAGRAM

- Baseband and pilot signals
- VFCT (Voice Frequency Carrier Teletype) signal
- Digital data signals
- Idle channel noise and status alarms
- Out-of-Service Test Procedure
- Monitoring Scheduling.

- Outputs from Data Collection
  - Monitoring signals of various kinds
  - Status alarms
  - Out-of-service test results
  - Test tone test configurations.

The Data Collection functional flow diagram is shown in Figure 10.

b. Performance Assessment. This function performs station equipment trending, in-service trouble detection, routine station equipment out-of-service test and alignment, and station alarm and status interpretation.

- Inputs to Performance Assessment
  - Monitoring Signals
  - Out-of-Service Test and Monitoring Results
  - Status Alarms
  - Status and Poll from man-machine interface
  - Scheduled Updates.

- Outputs from Performance Assessment
  - Monitoring Scheduling
  - Out-of-Service Test procedure
  - Alarms

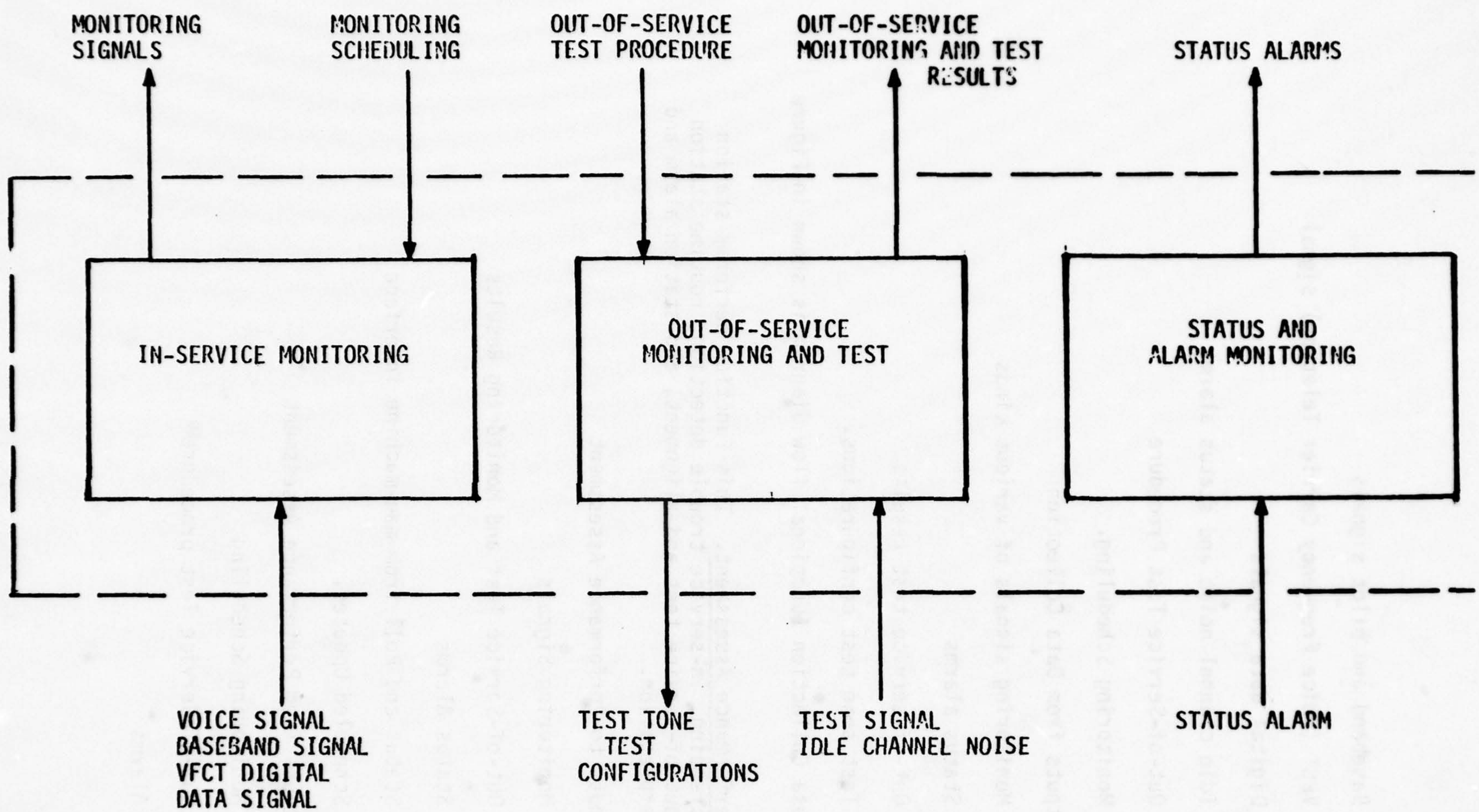


FIGURE 10 - TRANSMISSION DATA COLLECTION FUNCTIONAL FLOW DIAGRAM

- Trouble Flags
- Out-of-Service Test and Monitoring Results.

The Performance Assessment flow diagram is shown in Figure 11.

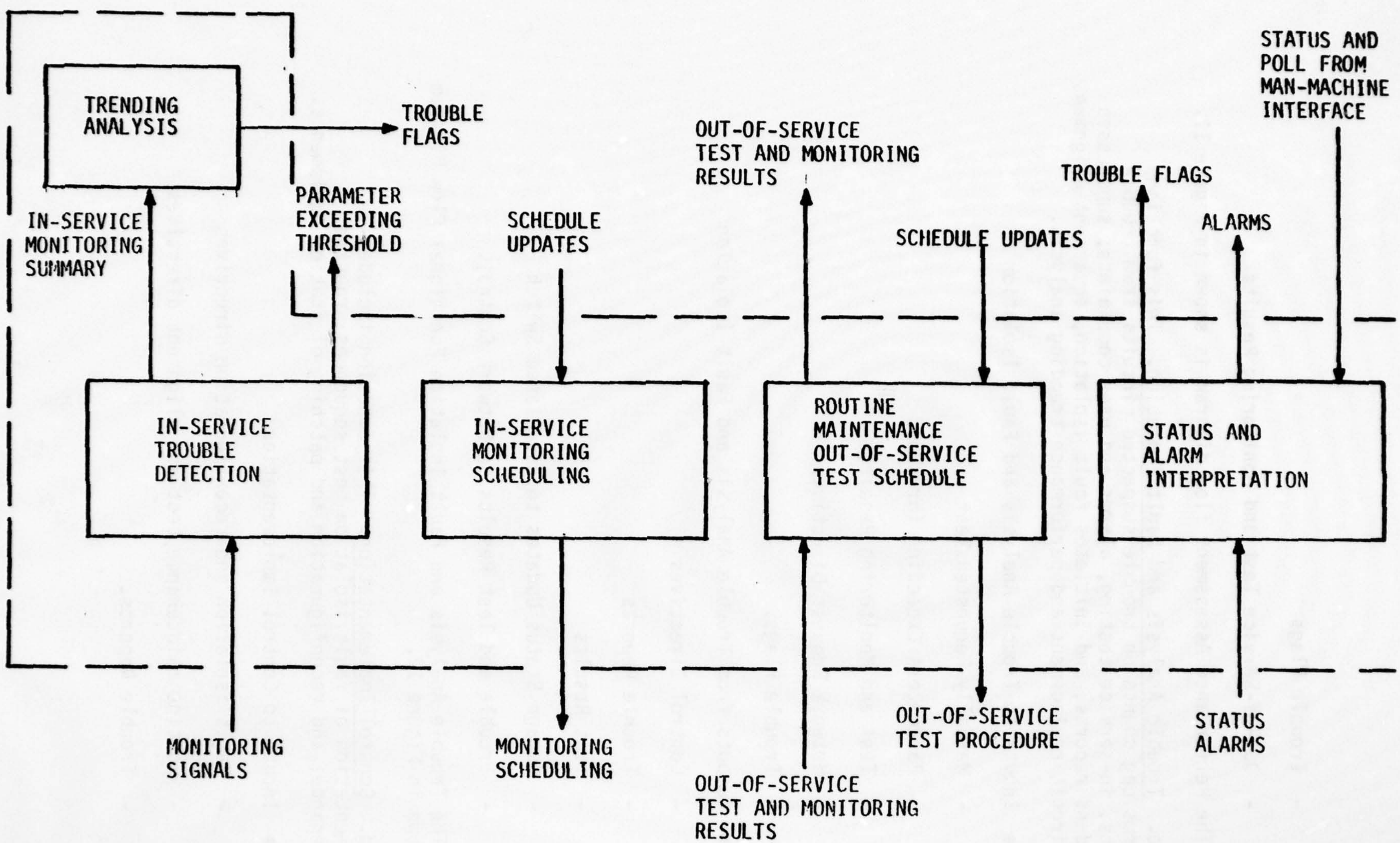
c. Trouble Analysis and Fault Isolation. This function performs peg counts on trouble suspected circuits from trouble reports, in-service testing, alarms and user complaints; suppresses redundant reports; and initiates fault isolation, equipment alignment and circuit replacement and performance trending analysis.

- Inputs to Trouble Analysis and Fault Isolation
  - Manually Requested Test
  - Parameters Exceeding Threshold
  - Test and Monitoring Results
  - Network Request Directives
  - Trouble Flags.
- Outputs from Trouble Analysis and Fault Isolation
  - Control Directives
  - Trouble Reports
  - Test Results
  - Outage Status Updates to Associated Switch
  - Trouble and Test Results to Network Control.

The Trouble Analysis and Fault Isolation Functional Flow Diagram is shown in Figure 12.

d. Control Implementation. This function includes implementation of fault isolation test sequences, routine maintenance, and reconfiguration and patching of station equipments.

- Inputs to Control Implementation
  - Fault isolation and reconfiguration directives
  - Routine maintenance test and alignment directives
  - Trouble Reports.



TRANSMISSION CONTROL PERFORMANCE ASSESSMENT
FIGURE 11 - FUNCTIONAL FLOW DIAGRAM

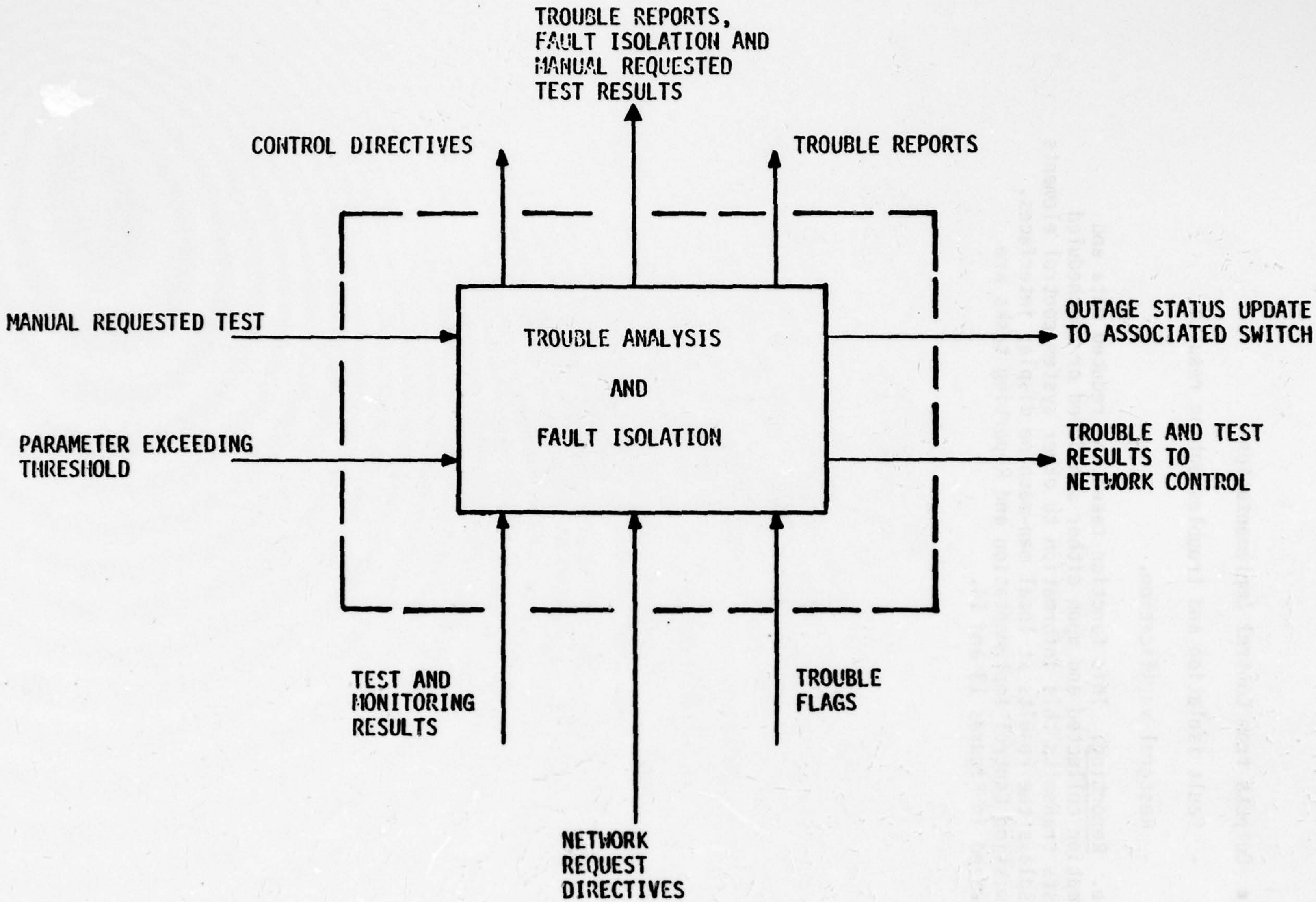


FIGURE 12 - TRANSMISSION CONTROL TROUBLE ANALYSIS AND FAULT ISOLATION FUNCTIONAL FLOW DIAGRAM

- Outputs from Control Implementation
  - Fault isolation and troubleshooting results
  - Restoral verification.

e. Reporting. This function takes the reduced data and information collected and upon either scheduled or unscheduled requests transmits this information to other system control elements or displays the results at local man-machine display interfaces. Transmission Control Implementation and Reporting tasks are summarized in Figures 13 and 14.

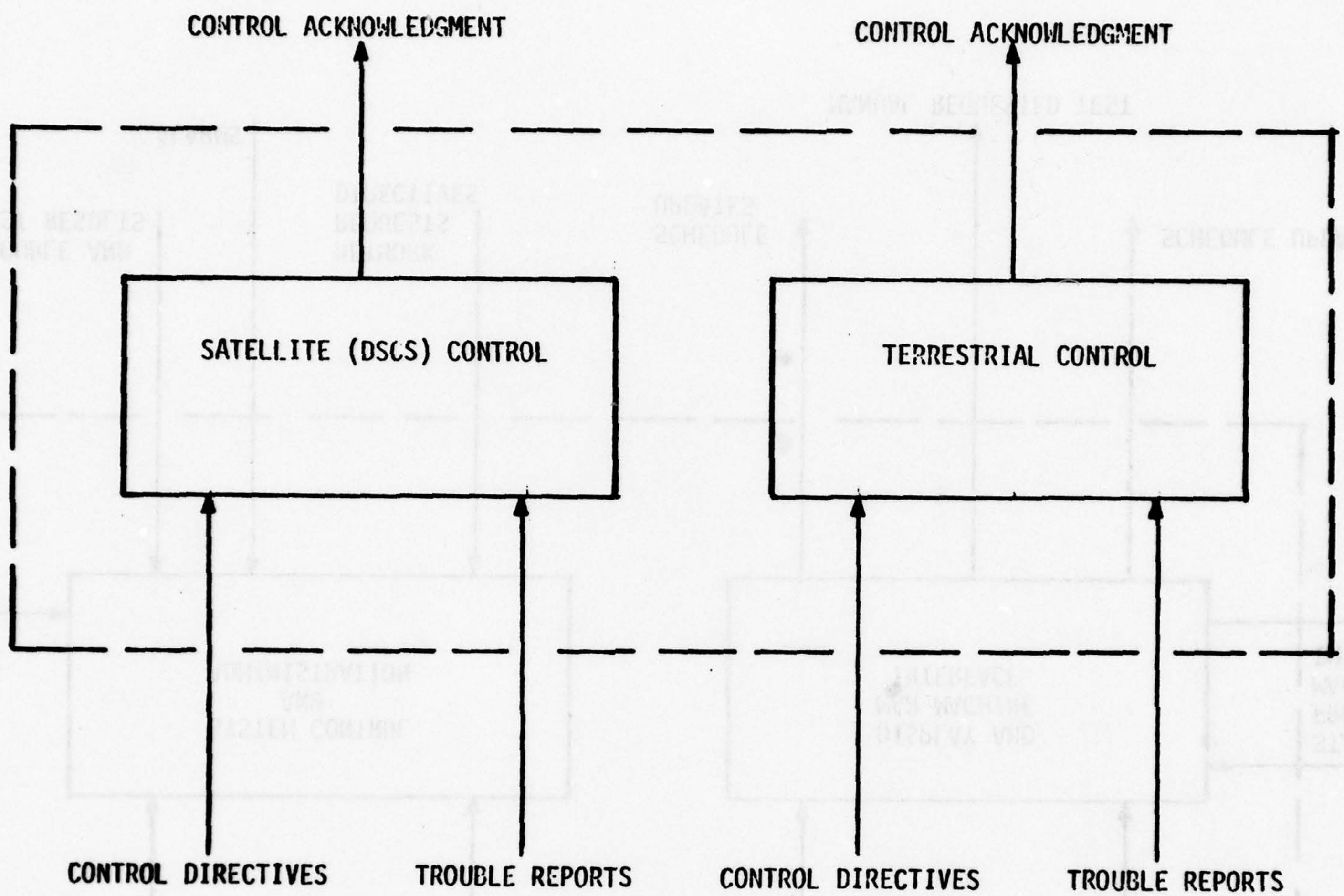


FIGURE 13 - TRANSMISSION CONTROL IMPLEMENTATION FUNCTIONAL FLOW DIAGRAM

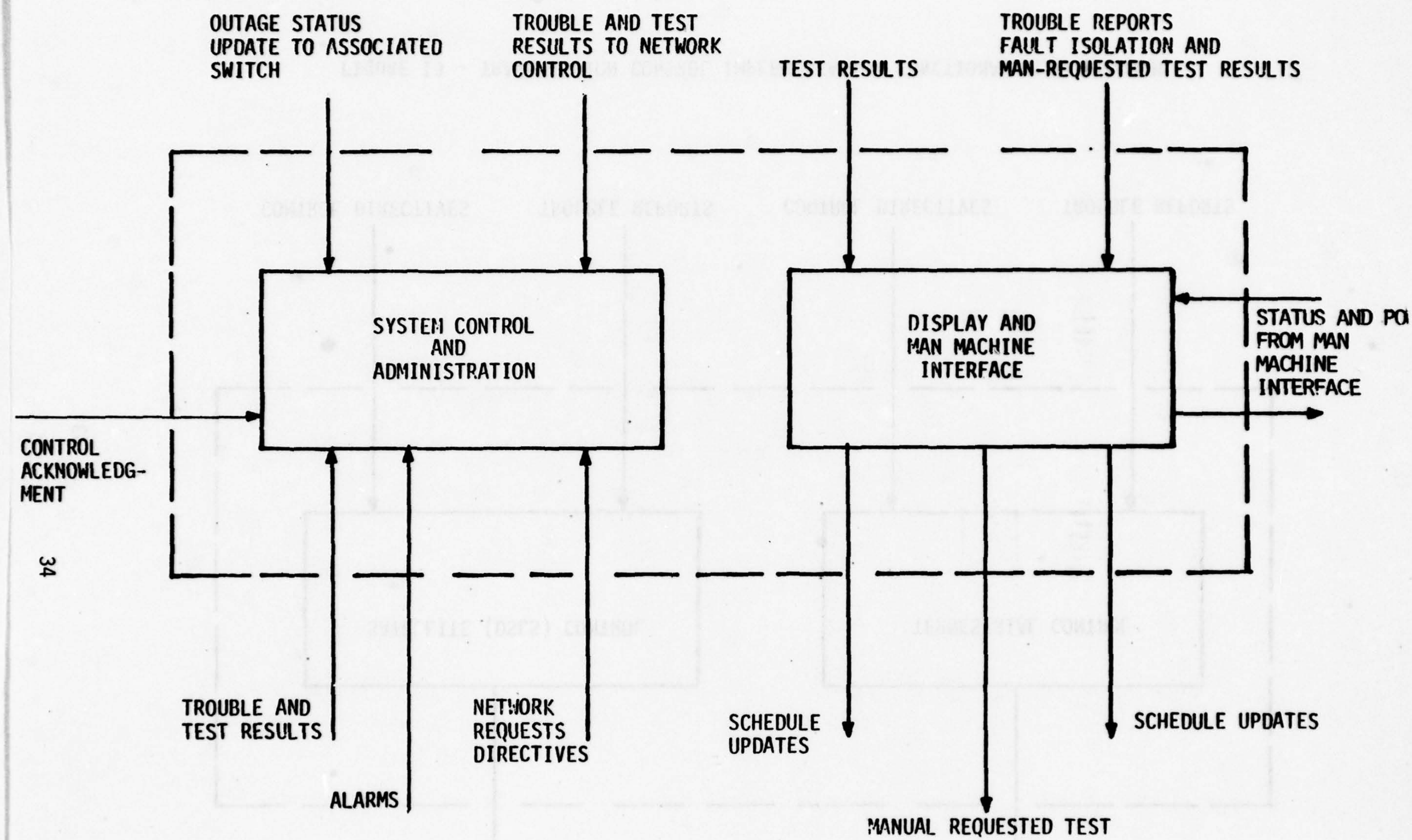


FIGURE 14 - TRANSMISSION CONTROL REPORTING FUNCTIONAL FLOW DIAGRAM

V. PRIMARY MEMORY SIZING CONSIDERATIONS

As was stated in section III, the System Control computer system is sized by means of a model with its own characteristic limitations. The model chosen for sizing the primary memory element of the nodal and sector level system control processors uses a buffered one-level functionally segmented contiguous overlayed storage medium. The sizing estimates produced for this model were first prepared for the total storage needed for subprograms and then analyzed for primary memory required for efficient overlayed operation. The sector and nodal level memories were both divided into the contiguous reserved areas as is shown in Figure 15. The sizes estimated in the following sections are based on use of 16-bit words.

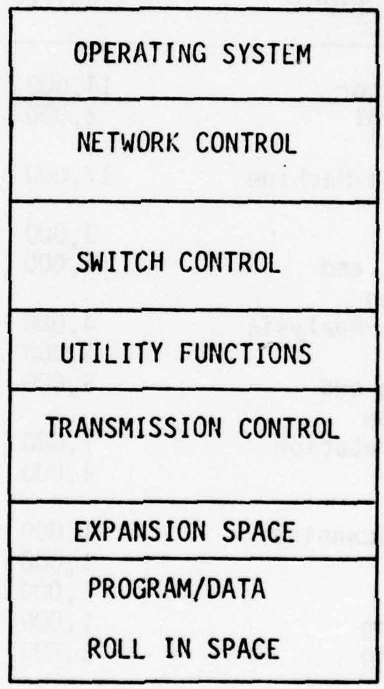


FIGURE 15 - FUNCTIONALLY SEGMENTED STORAGE

1. NODAL LEVEL SIZING ESTIMATES

Various studies have been completed analyzing the concept of integrated system control in the DCS /6, 7/. Utilizing the results of these efforts the nodal level primary memory requirements were computed and are shown in Tables II-VII. These tables display major functional areas, primary functions, and total required sizes, as well as practical overlay requirements.

Table II displays the switch control aspects associated with a nodal level processor.

TABLE II. NODAL LEVEL SWITCH CONTROL SIZING ESTIMATES

Switch Control Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Data Link Administrator	14,000	4,000
Switch Traffic Control Implementation	2,000	1,000
Local Display and Man-Machine Interface	17,000	5,000
Detection	3,000	3,000
Local Traffic, Alarm and Trouble Correlation	4,000	-
Local Switch Trouble Analysis	4,000	-
Traffic Monitoring	4,000	1,000
Call Data Monitoring and Traffic Calculation	5,000	2,500
Switch Alarm Interpretation	1,000	-
Trouble Sorting and Interpretation	4,000	-
Usage and Duration Scanning	1,000	1,000
Traffic Peg Count	1,000	1,000
Call Data Scanning	1,000	1,000
Switch Alarm Scanning	1,000	1,000
Trouble Card Scanning	1,000	1,000
Roll-in Space		5,000
	63,000	26,500

Table III displays the Network/Traffic Control Sizing estimates for the nodal level processor.

TABLE III. NODAL LEVEL NETWORK/TRAFFIC CONTROL SIZING ESTIMATES

Network/Traffic Control Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Switch Network Traffic Status Data Collection	10,000	2,000
Routine Maintenance Test,		
Alignment	2,000	-
Scheduling		
Reporting	5,000	5,000
Roll-In Space	-	2,000
	17,000	9,000

Table IV displays the sizing estimates for Transmission Control.

TABLE IV. NODAL LEVEL TRANSMISSION CONTROL SIZING ESTIMATES

Transmission Control Function	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Data Collection		
In-Service Monitoring	5,000	1,000
Out-of-Service Monitoring and Test	5,000	1,000
Status and Alarm Monitoring	1,000	1,000
Performance Assessment		
Status and Alarm Interpretation	4,000	1,000
Routine Maintenance (Out-of-Service-Test Scheduling)	5,000	500
In-Service Monitor Scheduling	2,500	500
In-Service Trouble Detection	5,000	1,000
Trending Analysis	15,000	1,000
Trouble Analysis and Fault Isolation	15,000	5,000
Control Implementation	10,000	5,000
Reporting		
Reporting Communication Software	5,000	2,500
Display Interfaces	9,000	4,000
Man-Machine Interaction	8,000	4,000
Roll-In Space		3,000
	89,500	30,500

Additional space is required for the executive and utility functions. A detailed estimate of total and resident required storage is shown in Table V.

TABLE V. NODAL LEVEL SIZING ESTIMATES FOR EXECUTIVE AND UTILITY FUNCTIONS

Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Executive Control/Task Scheduling	12,000	4,000
Message Error Checking	3,000	1,000
Data Conversion	3,000	500
Display Generation	10,000	2,000
Operator Interface	10,000	2,000
Orderwire Protocol	7,000	-
Maintenance and Diagnostics	1,000	-
System Initialization and Bootstrap	500	-
Disc I/O Handle	15,000	5,000
Processor Monitor	5,000	500
System Fault Recognition	5,000	-
Interrupt Administration	1,000	1,000
	72,500	16,000

Additional space is required for data tables and program data roll-in space. The estimates for these functions is shown in Table VI.

TABLE VI. NODAL SIZING ESTIMATES FOR SWITCH CIRCUIT AND EQUIPMENT TABLES AND ROLL-IN SPACE

Functions	No. of Words (16-Bit Words)
Switch Circuit Tables	9,000
Equipment Tables	9,000
Control Threshold References	500
Task Scheduling and Pointer	400
Interrupt	300
Maintenance Program	500
Data Link Queue	1,000
Function Interface Hopper	1,200
Near Term Trouble Record	1,200
Call Data Scratch Pad	8,000
Traffic Parameter	1,500
Trouble Analysis	3,000
Alarm Status Memory	800
	36,400

The resident sizing estimates for the major System Control functions are summarized in Table VII.

TABLE VII. RESIDENT FUNCTIONAL SIZING ESTIMATES

Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Operating System and Utility Functions	72,500	16,000
Network/Traffic Control	17,000	9,000
Switch Control	63,000	26,500
Transmission Control	89,500	30,500
Program/Data Roll-In Space	36,400	36,400
	278,400	118,400

2. SECTOR LEVEL SIZING ESTIMATES

In a similar fashion to the preceding analysis of the nodal level processor primary memory requirements, decompositions were performed on the sector level equipments and are shown in Tables VIII-XIII. Table VIII displays the switch control aspects associated with the sector level processor.

TABLE VIII. SECTOR LEVEL SWITCH CONTROL SIZING ESTIMATES

Switch Control Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Data Link Administrator	14,000	4,000
Man-Machine Interface	10,000	-
Reporting Functions	5,000	5,000
Roll-In Space		2,000
	29,000	11,000

Table IX displays the sector level network traffic control sizing estimates.

TABLE IX. SECTOR LEVEL NETWORK/TRAFFIC CONTROL SIZING ESTIMATES

Network/Traffic Control Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Network Fault Isolation	12,000	6,000
Network Trouble Analysis	9,000	3,000
Switched Network Traffic and Status Collection	10,000	2,000
Switched Network Traffic Analysis and Control	10,000	3,000
Network Service Evaluation	2,000	1,000
Network Reconfiguration	3,000	1,000
Routine Maintenance Test Alignment Scheduling	5,000	1,000
Reporting	5,000	5,000
Roll-In Space		2,000
	56,000	24,000

Table X displays the sizing estimates for sector level Transmission Control functions.

TABLE X. SECTOR TRANSMISSION CONTROL SIZING ESTIMATES

Transmission Control Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Data Collection	11,000	2,500
Performance Assessment	30,000	5,000
Trouble Analysis	20,000	5,000
Control Implementation	10,000	2,000
Reporting	25,000	8,000
Roll-In Space	-	3,000
	96,000	25,500

Additional space is required for the executive and utility functions. Detailed estimates of total and resident required storage are shown in Table XI.

TABLE XI. SECTOR LEVEL SIZING ESTIMATES FOR EXECUTIVE AND UTILITY FUNCTIONS

Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
File and Data Base Management	55,000	10,000
Executive Control/Task Scheduling	12,000	4,000
Message Error Checking	3,000	1,000
Data Conversion	3,000	500
Display Generation	10,000	2,000
Operator Interface	10,000	2,000
Orderwire Protocol	7,000	-
Maintenance and Diagnostics	1,000	-
System Initialization and Bootstrap	500	-
Disc I/O Handle	15,000	5,000
Processor Monitor	5,000	500
System Fault Recognition	5,000	-
Interrupt Administration	1,000	1,000
	127,500	26,000

Additional space is required for data tables and program data roll-in space. The estimates for these functions are shown in Table XII.

TABLE XII. SECTOR SIZING ESTIMATES FOR SWITCH CIRCUIT AND EQUIPMENT TABLES AND ROLL-IN SPACE

Functions	No. of Words (16-Bit Words)
Switch Circuit Tables	9,000
Equipment Tables	9,000
Control Threshold References	500
Task Scheduling and Pointer	400
Interrupt	300
Maintenance Program	500
Data Link Queue	1,000
Function Interface Hopper	1,200
Near Term Trouble Record	1,200
Call Data Scratch Pad	8,000
Traffic Parameter	1,500
Trouble Analysis	3,000
Alarm Status Memory	800
	36,400

The resident sizing estimates for the major System Control functions are presented in Table XIII.

TABLE XIII. RESIDENT FUNCTIONAL SIZING ESTIMATES

Functions	Total 16-Bit Words Required	Overlayed 16-Bit Words Required
Operating System and Utility Functions	127,500	26,000
Network/Traffic Control	56,000	24,000
Switch Control	29,000	11,000
Transmission Control	96,500	25,500
Program/Data Roll-In Space	36,400	36,400
	345,400	122,900

VI. SECONDARY MEMORY SIZING CONSIDERATIONS

In determining the sizing requirements of secondary memory for use in data base storage, program storage and scratch space, consideration must be given to three parameters: size, access time and transfer time. In the proposed model for a System Control processor, space must be allocated on secondary storage for copies of all required data bases, programs, tables and forms, as well as providing for adequate scratch space for the creation of new file elements.

The access time should not be greater than the time generally required to change all the necessary pointers in the virtual systems hierarchy. This is a basic requirement because of the methods by which modern computer systems operate. What is generally being considered here is the equivalence of the time to set up secondary memory segment (access time) with the time for the processor to switch to a new virtual primary memory segment (time to change major pointers). By equating these two "set up" times, degradation of task execution should be minimized. Therefore, we are trying to match the processor with its associated virtual storage medium as closely as possible to tune the system for maximum performance. Existing computer systems that could be utilized for this purpose were investigated and the time required to set up program transfers was found to be in the area of 2 to 10 milliseconds. Due to this time restriction in resetting primary virtual memory pointers, a disc access time of under 10 milliseconds is recommmended.

In view of these requirements, plus the need for reliability, a multiple set of disc units was considered necessary for secondary storage. Multiple discs were decided upon because the disc controller is a major part of disc unit costs, and a single disc controller can usually control up to eight disc units. In this case, multiple smaller disc units are more reliable than a single large disc. Also, small disc units usually have faster access and transfer speeds. In determining the size of the required discs we look not only at core resident programs but also at the disc resident programs, major data bases, report forms, operating system requirements and various copies of programs in different forms, (source, relocatable, absolute). From the CNCE Software PDR minutes /8/, it was determined that a minimum of two 2-megaword disc units would be required to store just the various forms of the programs, a minimal data base, the operating system, and the required operator required forms. This gave little room for expansion, so a requirement of two 4-megaword discs was considered minimal for the nodal level, while three 4-megaword discs for the sector level were indicated.

Additional requirements for tape storage were included as a backup measure for loading systems when the discs are inoperative, and for storage of required forms.

In estimating required transfer speed, it was useful to stipulate that the transfer of a major program segment should not degrade human use of the machine. It was considered expedient to require segment transfers to take less than 100 milliseconds. Considering maximum program segment sizes to be approximately 10,000 words long, this requires that the disc transfer speed be no slower than 10 microseconds per word. These speeds for disc access and transfer are achievable on disc pack and fixed head disc units.

VII. PROCESSOR SPEED CONSIDERATIONS

Memory cycle times as well as processor cycle times have very little application to a sizing study without extensive elaboration. Existing minicomputers such as the PDP-11 series have relative memory cycle times from about 300 nanoseconds for bipolar memories to 1 microsecond for core. Internal processor minor-cycle times are approximately 100 nanoseconds to 1 microsecond. But without a determination of a specific processor and its instruction execution procedure it is only useful to state cycle times of main memory and relate this factor to the secondary storage medium transfer rate.

If we look at an eight-bank interleaved memory with 1 microsecond cycle time we find that its transfer speed is 1 million words per second. Because of the interleaving, we can theoretically transfer from a bank every 125 nanoseconds at the maximum rate. In this case an 8 million word per second transfer rate is possible. Referring back to the disc transfer rate we note that we required a transfer rate of at least 100,000 words per second. This is approximately a two order magnitude difference, which is reasonable between levels in an hierarchical memory system.

If the processor described by the above parameters would execute an average instruction (memory to register) in four cycles, this would allow for a processor bandwidth of 250 KOPS (thousand operations per second). By estimating that the scan procedure takes approximately 1000 operations we deduce that a channel scan can be achieved by this model in 4 milliseconds. These numbers seem to allow the processor to scan 1000 channels in 4 seconds assuming no other task is executing. When we consider the additional processing required on this scan data to take two orders of magnitude more than the scan, we estimate that this scan process of 1000 channels can be completed in under 7 minutes, which is quite within the bounds of our requirements and allows for all other operations to be performed.

The major problem with this sizing estimate is that it takes into account only the quiescent condition and not the processor in a stress condition. If this is done we will find that some degradation of performance will always be present in a communications stress environment, thus requiring reasonably large sizing margins.

VIII. DISPLAY/JOURNALING REQUIREMENTS

Terminal factors can be discussed in two parts: those that relate to the terminal's interface with the processor and those that relate to its interface with the operator. These two aspects are linked in the overall consideration of the logic, or "intelligence," that is built into the terminal, and hence, to a large degree, its cost.

At the sector level, the operator is concerned most with network/traffic control, while at the nodal level the operator is concerned most with switch control and transmission control. In both cases the operator must be able to interact with the data base to determine status and to update or insert new information. Therefore, at a minimum it is recommended that at least two CRT's and possibly three be provided at the nodal level so that the current status on switches and transmission facilities is available to the operator. This also allows the operator independent query capability on the data bases. At the sector two CRT's are required - one for network/traffic control and the other for query/updates of the data base.

In determining the number of CRT displays required at a site it is important to look at what displays could be required at any one time and the independence and interelationships of the desired displayed data. Switch and Transmission status information is relatively independent and thus requires independent displays. When an operator is looking at one display for status he will very often want to query the system regarding a number of points on the display. To enable the operator to accomplish this task without remaking the reference display or writing notes between queries an additional display for query/response traffic is required.

A human performance goal would be to input to the screen a page of information within 3 seconds of query. This speed can be achieved at a 9600 baud rate. Hard copies of CRT displays are sometimes required, requiring a line printer capable of printing at the 9600 baud rate. Stated in another way, the line printer must print 600 lines per minute in full buffered mode.

IX. COMMUNICATIONS REQUIREMENTS

The communications requirements of System Control processors will be estimated by first determining the connectivity relationships among the various levels in consideration and then by estimating the expected types of traffic utilizing this connectivity. The connectivity relationships of the sector and nodal control levels for the tech control requirements are defined in the Automated Technical Control (ATEC) System Description. Each Sector Control Subsystem (SCS) shall be capable of interfacing with a minimum of three other SCS's via 2400 baud full duplex data links. Each SCS shall also interface with a maximum of five Nodal Control Subsystems (NCS's) via separate 2400 baud full duplex digital data links for each SCS/NCS interface. The SCS shall also interface with the Theater Control Level Area Communications Operations Center (ACOC) via 2400 baud full duplex digital data links.

In addition each NCS shall be capable of interfacing with a single SCS and a maximum of six communications links to its subordinate levels. An additional capability shall also be provided for future incorporation of a single communications link to interface with a Communications Nodal Control Element (CNCE) of the Tactical Communications Control Facility (TCCF) and two additional interface links to other System Control functions. Diagrams of the connectivity relationships are shown in Figures 16 and 17.

After a connectivity relationship is established, a list of functional requirements must be determined. For ease of analysis the elements of System Control transmission were divided into the following five categories:

- Status Reports
- Traffic Reports
- Data Base Updates
- Query/Response Traffic
- Administrative Traffic.

For each of these areas a characterization of parameters must be developed. The major parameters of interest are:

- Average Message Length
- Average Transmission Time
- Utilization Factor
- Mean Delay Time.

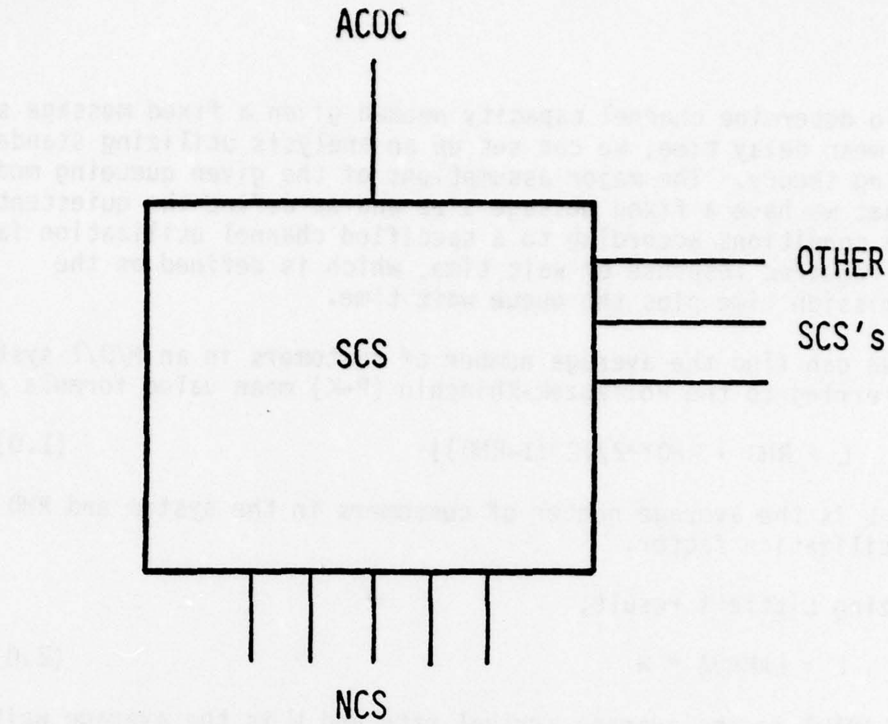


FIGURE 16 — SCS CONNECTIVITY RELATIONSHIPS

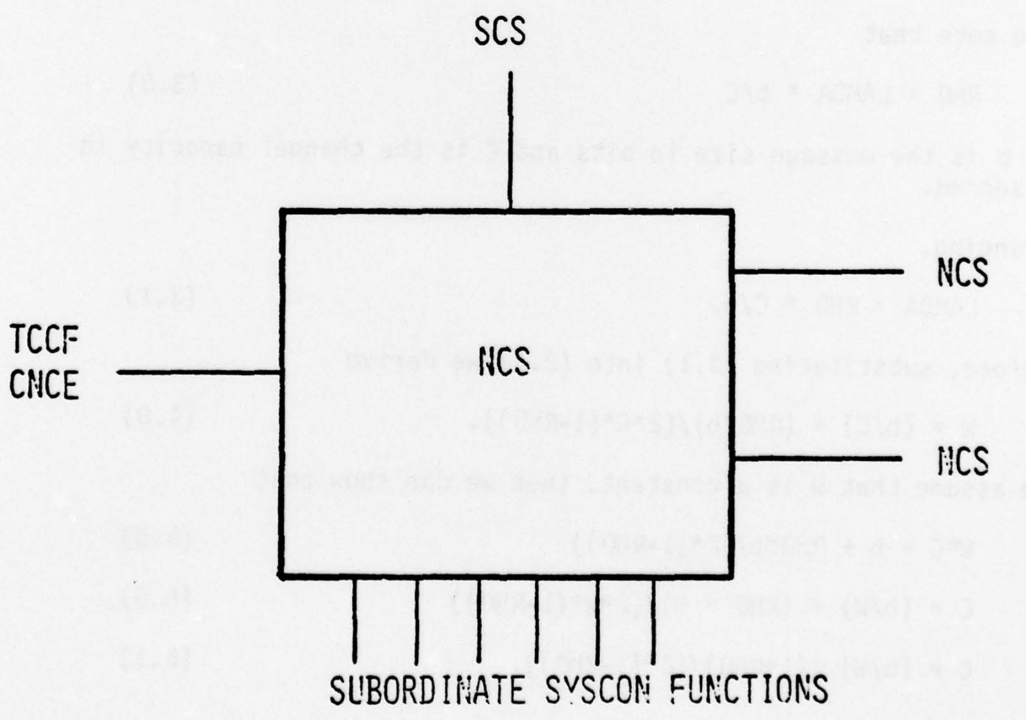


FIGURE 17 — NCS CONNECTIVITY RELATIONSHIPS

To determine channel capacity needed given a fixed message size and a mean delay time, we can set up an analysis utilizing standard queueing theory. The major assumptions of the given queueing model are that we have a fixed message size and we define the quiescent and stress conditions according to a specified channel utilization factor and a required response or wait time, which is defined as the transmission time plus the queue wait time.

We can find the average number of customers in an M/D/1 system by referring to the Pollaczek-Khinchin (P-K) mean value formula /9/

L = RHO + RHO**2/(2*(1-RHO)) (1.0)

where L is the average number of customers in the system and RHO is the utilization factor.

Utilizing Little's result,

L = LAMADA * W (2.0)

when LAMADA is the average arrival rate and W is the average wait time.

We can show

W = L/LAMDA. (2.1)

But we note that

RHO = LAMDA * b/C (3.0)

where b is the message size in bits and C is the channel capacity in bits/second.

Rearranging,

LAMDA = RHO * C/b. (3.1)

Therefore, substituting (3.1) into (2.1) we derive

W = (b/C) + (RHO*b)/(2*C*(1-RHO)). (4.0)

If we assume that W is a constant, then we can show that

W*C = b + RHO*b/(2*(1-RHO)) (5.0)

C = (b/W) + (RHO * b)/(2*W*(1-RHO)) (6.0)

C = (b/W) ((1+RHO)/(2*(1-RHO)). (6.1)

Equation (6.1) therefore defines channel capacity in terms of average wait time, average message size, and the utilization factor.

If we look at both the quiescent (Q) and the stress condition environments of the previously defined five categories of System Control communications functions, we can estimate appropriate communications requirements of the System Control processor.

Table XIV summarizes the assumptions of average message size, b, average delay time, W, and average utilization, RHO, and the resultant calculated required channel capacity for the five categories of System Control traffic. The basic assumptions used in this table are variations of the statistics found by the Computer Sciences Corporation (CSC) in analyzing the current DCS System Control subsystem and comparing it with various alternative architectures /10/. The numbers are based on the analysis of the M/D/1 queue model described above.

Figures 18 through 21 display the relationships between channel capacity and utilization factors for fixed message sizes of 525, 400, 320, and 24 kilobits and 800 bits, with various wait times. Figure 22 displays the relationships between wait time and utilization for various channel capacities of 32, 19.2, 9.6, 4.8 and 2.4 kb/s, assuming a fixed message size of 525 kilobits. From this chart we can easily see that a 525 kilobit message will have an average wait time of approximately 850 seconds (14.17 minutes) at 85% utilization on a 2.4 kilobit channel and only 62 seconds (one minute) with a 32 kilobit channel at 85% utilization. Note that the relationships among the various curves are linear in that a 19.2 kb/s channel is twice as big as a 9.6 kb/s channel and its wait time is exactly one half the wait time of the 9.6 kb/s channel for equal utilization factors. But note that smaller channels will have the tendency to have higher utilization rates if the same amount of information is transmitted, and this will have an adverse effect on the wait time of that channel.

A major goal of this analysis is to put a reasonable upper bound on the communications capability of a System Control processor element. This upper bound can be determined by assuming a fixed connectivity with fixed channel capability and a 100% utilization factor. The assumed connectivity relationships are not based on a physical connectiveness criterion but rather on an information flow criterion of connectiveness. In this regard we will assume for the nodal control element 10 channels of administrative traffic at 2.4 kb/s and 3 channels at 32 kb/s, each, for transmitting status reports, traffic reports and data base updates at 32 kb/s. This, then, requires the NCS to support communications requirements of up to 120 kb/s. The sector control level, due to its position in the hierarchy and its requirement to communicate with lower level NCS's at 32 kb/s rates, will require an upper bound of nine 2.4 kb/s

channels for administrative traffic as well as up to seven channels transmitting large amounts of data in the form of status reports, traffic reports and data base updates at 32 kb/s for a total communications requirement of 245.6 kb/s. Although these upper bounds are quite large, the 245.6 kb/s rate is only a 6.14% overhead factor on a relatively slow processor that is capable of moving the data in 16-bit word blocks with one instruction, with an average execution time of 4 microseconds.

TABLE XIV. CHANNEL CAPACITY REQUIREMENTS

Type of Traffic		Environmental Conditions: Quiescent	Environmental Conditions: Stress
Status Reports	b	400,000 bits	400,000 bits
	W	60 sec	60 sec
25K 16 bit	RHO	.2	.8
words	C	7.5 kb/s	20 kb/s
Traffic Reports	b	320,000 bits	320,000 bits
	W	60 sec	120 sec
20K 16 bit	RHO	.2	.8
words	C	6.0 kb/s	8 kb/s
Data Base Updates	b	525,000 bits	525,000 bits
	W	60 sec	300 sec
32K 16 bit	RHO	.2	.8
words	C	9.9 kb/s	5250 b/s
Query Traffic	b	800 bits	800 bits
	W	2 sec	4 sec
	RHO	.2	.8
50 16 bit words	C	450 b/s	600 b/s
Response Traffic	b	24,000 bits	24,000 bits
	W	60 sec	120 sec
	RHO	.2	.8
1500 16 bit words	C	450 b/s	600 b/s
Administrative	b	24,000 bits	24,000 bits
	W	60 sec	120 sec
	RHO	.2	.8
1500 16 bit words	C	450 b/s	600 b/s

b - message size in bits
W - average waiting time in seconds
RHO - channel utilization factor
C - channel capacity in bits/second

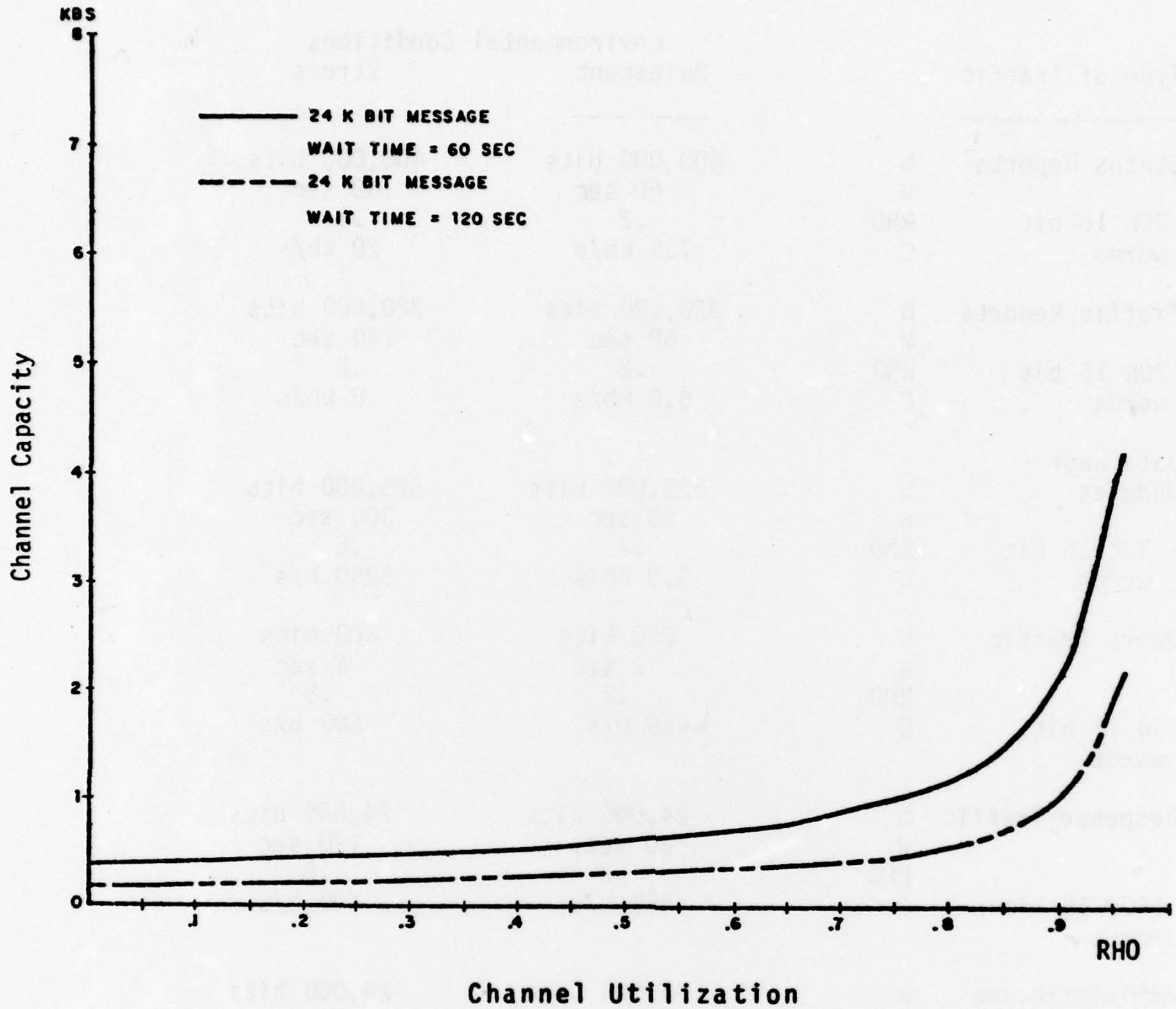


FIGURE 18 - M/D/1 QUEUE FOR 24 KILOBIT MESSAGE

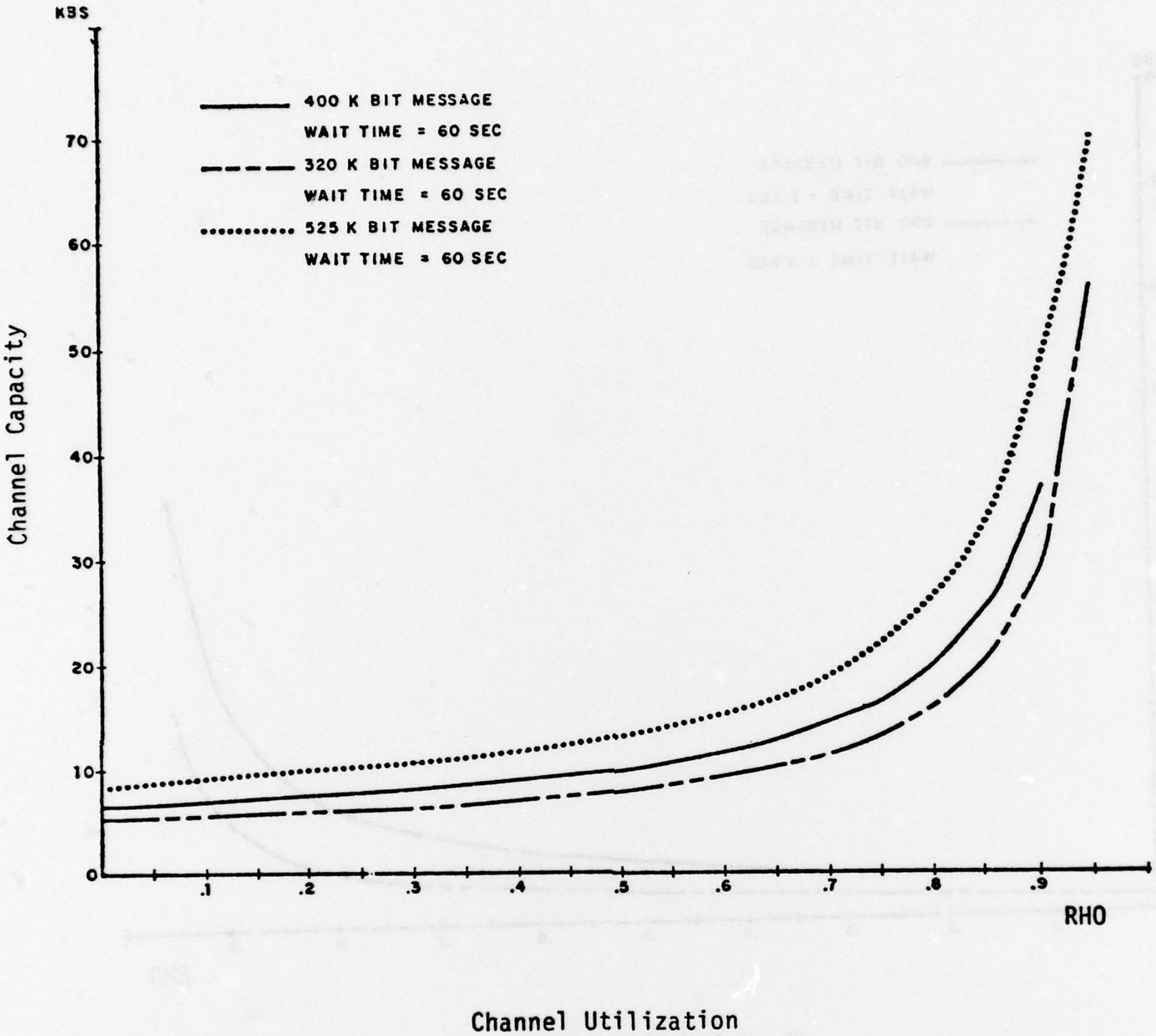


FIGURE 19 - M/D/1 QUEUE FOR 60 SECOND WAIT TIMES

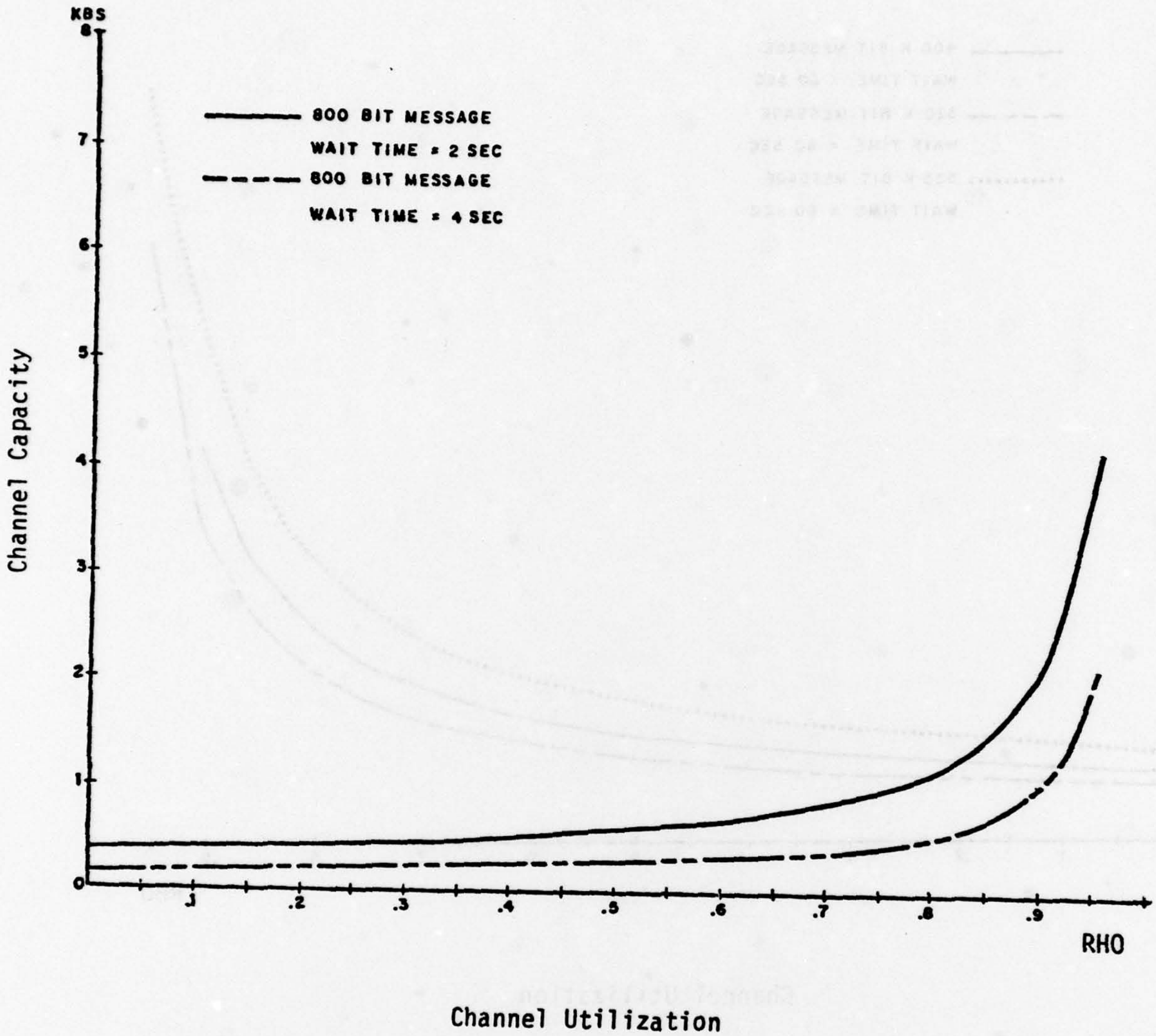


FIGURE 20 - M/D/1 QUEUE FOR 800 BIT MESSAGES

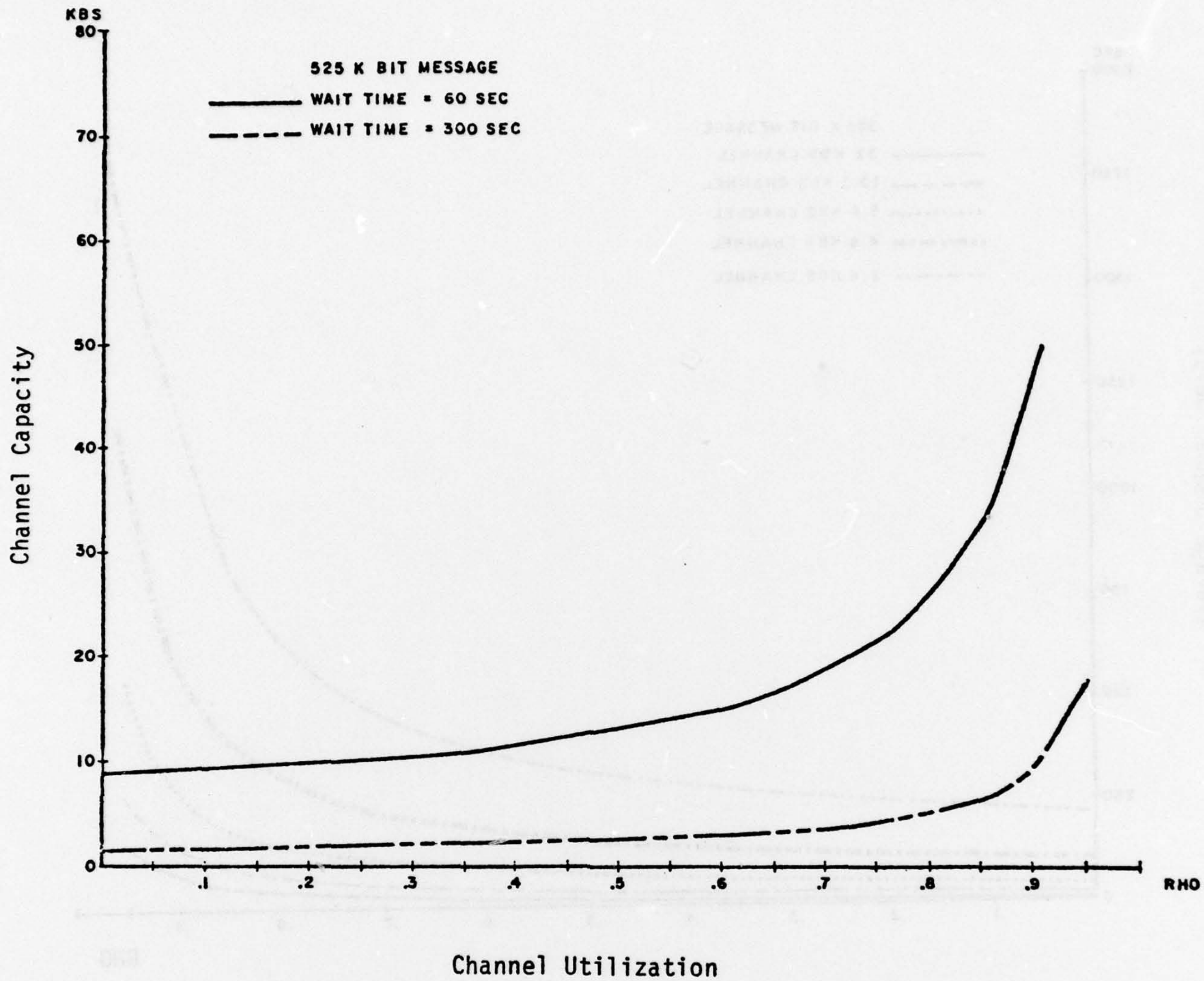


FIGURE 21 - M/D/1 QUEUE FOR 525 KILOBIT MESSAGES

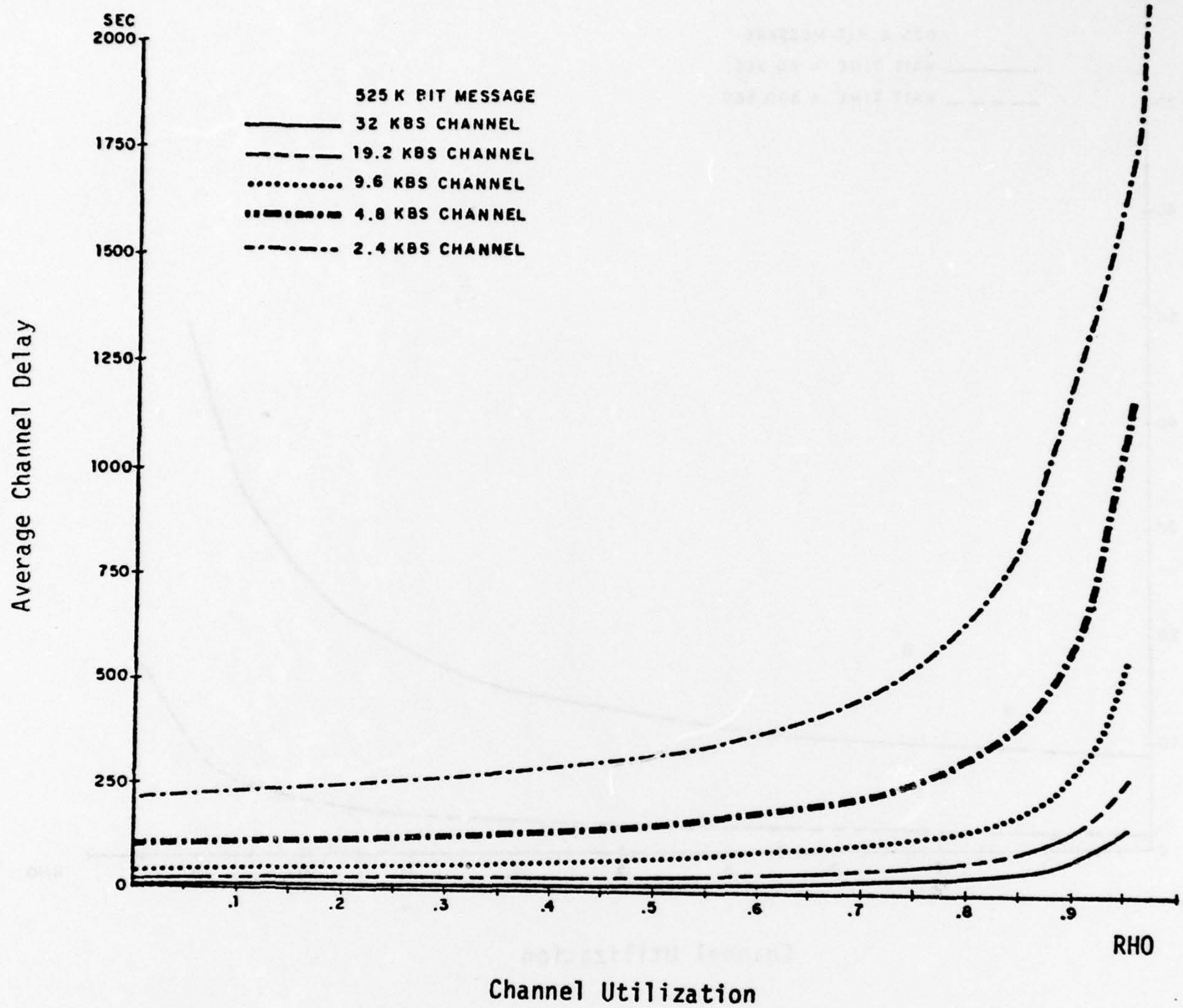


FIGURE 22 - M/D/1 QUEUES FOR DIFFERENT CHANNEL CAPACITIES

X. CONCLUSIONS

The recommended sizing for a System Control processor incorporates a processor that has the capability to address at a minimum 128K words of primary memory with a maximum memory cycle time of 750 nsec. The 128K memory size is the smallest standard memory configuration capable of containing our estimated overlayed storage requirement of 122, 900 words that was determined in Section 5 of this report. At a minimum, two 4-megaword disc units are required by the sizing and reliability constraints considered in the analysis. The Sector Control level requires two CRT displays, while the Nodal Control level may require up to three CRT displays if both Switch and Transmission Control functions are performed at that site. In addition, a printer that can be line-dropped off the displays port is required for preparing hard copies and journals. This line printer must be capable of printing 600 lines per minute. After an extensive analysis using queueing models for a simplified Control Facility with fixed message sizes and a fixed connectivity requirement, the communications processing requirements of the System Control processor were determined. The sector level due to its high connectivity with other computer systems (nodal, sector and area centers) requires a rather high communications processing capability of 245.6 kb/s, while the nodal level with fewer connections to medium size computer systems requires a communications processing capability of 120 kb/s. In both cases the communications processing capability imposes no more than a 10 % overhead on the recommended System Control processing capability, and is therefore within normal operating bounds.

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